Chapter 1

4th Industrial Revolution Smart Factory Innovation Activities

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1.1 Smart Factory Based on the Fourth Industrial Revolution

(1) Overview of Implementation

The Fourth Industrial Revolution (Industry 4.0) is an industrial innovation paradigm that intelligentizes manufacturing, services, and industries as a whole, based on digital technologies such as ① AI (Artificial Intelligence) and the Internet of Things, ③ Big Data, ④ Cloud, ⑤ Robotics, and ⑥ Cyber Physical Systems (CPS).

A Smart Factory is a core embodiment of this Fourth Industrial Revolution; it is an intelligent manufacturing system that connects production facilities with information systems to enable the factory to independently collect, analyze, judge, and optimize data.

In other words, it is a future-oriented manufacturing innovation system that realizes ① Automation, ② Digitalization, ③ Connectivity, ④ Intelligence, and ⑤ Autonomy. In particular, the plant[1)] or process industry has significant characteristics such as ① continuous processes, ② large-scale facilities, ③ high energy consumption, and ④ the importance of process safety, so smart factory-based manufacturing innovation becomes the core of manufacturing competitiveness.

※ Explanation : 1. the plant industry is also referred to as the process industry.

(2) Definition of the Fourth Industrial Revolution

1) Definition

The Fourth Industrial Revolution refers to a new stage of industrial revolution that realizes hyper-connectivity and hyper-intelligence-based industrial innovation by integrating digital technology with physical manufacturing systems.

2) Key Features

① Hyper Connectivity: Refers to an environment where connections go beyond people to people, and all entities including people, objects, devices, and machines are densely connected through networks to interact in real time.

② Super Intelligence: Refers to an intelligent system where Artificial Intelligence (AI) and Big Data combine to surpass or assist human learning, reasoning, and judgment capabilities.

③ Smart Automation: Going beyond traditional mechanical and simple repetitive automation, it refers to an intelligent automation system where AI and the Internet of Things (IoT) combine to enable machines to independently recognize situations, make judgments, and learn to derive optimal results.

④ Big Data Analytics: Refers to a core driving force that creates new value and economic momentum through hyper-connectivity and super-intelligence, going beyond simply processing vast amounts of data.

⑤ Autonomous Operation: Refers to an intelligent autonomous control system in which artificial intelligence (AI), the Internet of Things (IoT), and big data are combined to enable machines or systems to independently recognize and judge situations, derive optimal results, and execute them without direct human intervention.

(3) Stages of Industrial Revolution Development and Characteristics

① 1st Industrial Revolution: Machinery

② 2nd Industrial Revolution: Mass Production

③ 3rd Industrial Revolution: Automation

④ 4th Industrial Revolution: Intelligence

(4) Definition of Smart Factory

1) Definition

A smart factory refers to an intelligent factory that optimizes the entire production process in real time by connecting equipment, processes, logistics, quality, and energy based on IoT and AI.

2) Main Objectives

① Productivity Improvement: Productivity per person, productivity per hour, productivity added

② Quality Stabilization: Zero Defects, ③ Breakdown-Free: Breakdown Zero

④ Energy Saving: Energy Cost Saving

⑤ Safety Assurance: Achieving Zero Accidents (Smart SHE)[1)]

(5) Key Components of a Smart Factory

① IoT: Real-time data collection, ② AI: Analysis, prediction, and judgment

③ Big Data: Manufacturing data analysis, ④ CPS: Cyber Physical System

⑤ Cloud: Integrated platform, ⑥ Robotics: Smart automation

(6) Characteristics of Smart Factory Operation

① Production: Smart Production (an intelligent production method where all equipment and systems within the factory are connected to IoT and AI, allowing them to independently assess situations based on data and optimize manufacturing processes).

② Quality: AI Quality Control (referring to an intelligent manufacturing paradigm that integrates the Internet of Things (IoT), big data, and artificial intelligence to predict and prevent defects in the production process in advance, and to inspect and automatically control quality in real-time using visual data).

③ Equipment: Predictive Maintenance (a maintenance strategy that utilizes IoT sensors and AI to collect and analyze equipment data in real-time to predict failure times and take preemptive measures).

④ Logistics: Smart Logistics (a system that integrates IoT, AI, and big data throughout the manufacturing process to automate and intelligentize the logistics process from material procurement to product shipment).

⑤ Energy: Smart Energy (an eco-friendly operation method that utilizes IoT sensors and AI to monitor, analyze, and optimize energy consumption within the factory in real-time to reduce waste).

⑥ Safety: It is characterized by intelligent SHE (referring to a system that integrates advanced ICT technologies such as IoT, AI, and big data into the field to manage workers' safety, health, and environment in real time and predict and prevent accidents in advance).

(7) Stages of Smart Factory Development and Characteristics

① Basic Automation: Equipment Automation

② Digitalization: Data Collection, ③ Connectivity: System Integration

④ Intelligence: AI Analysis, ⑤ Autonomy: Autonomous Factory

(8) Characteristics of Smart Factory in Plant Industry

① Continuous Process: Continuous manufacturing process

② Large-scale Equipment: Plant-type large-scale equipment

③ Energy: Energy-intensive type, ④ Process Safety: Smart PSM[1)]

⑤ Quality Management: Real Time Quality

※ Explanation: 1. Smart PSM (Smart Process Safety Management)

(9) Linking C-TPM Activities with Smart Factories

① Autonomous Maintenance: Smart Autonomous Maintenance

② Planned Maintenance: Predictive Maintenance

③ Quality Maintenance: AI Quality

④ Individual Improvement: Digital Individual Improvement

⑤ SHE: Intelligent Safety, Health, and Environment

(10) Expected Effects of Smart Factory

① Productivity: Increased production volume, ② Quality: Reduced defects

③ Equipment: Prevention of breakdowns, ④ Energy: Cost reduction

⑤ Safety: Prevention of accidents, ⑥ Operations: Real-time optimization

(11) Future Directions of Smart Factories

① AI Factory: AI-centric operation, ② Dark Factory: Unmanned factory

③ Intelligent Factory: Self-learning factory

④ Hyper Automation: Hyper-automation (all processes capable of automation are subject to automation)

⑤ ESG Factory: Eco-friendly manufacturing

(12) Summary of Key Implementation Points

The Smart Factory of the Fourth Industrial Revolution is a hyper-connected and hyper-intelligent manufacturing innovation system based on AI, IoT, and Big Data.

A Smart Factory is an intelligent manufacturing system that optimizes all areas in real time, including ① production, ② quality, ③ equipment, ④ logistics, ⑤ energy, and ⑥ safety.

In particular, the core of Smart Factory C-TPM is the system of ① Predictive Maintenance, ② AI quality management, ③ Digital improvement, ④ Smart SHE, and ⑤ ESG manufacturing innovation.

In the plant industry, ① continuous process optimization, ② process safety enhancement, ③ energy saving, ④ non-stop production, and ⑤ AI-based operation are very important.

In other words, the key is to realize a future-oriented Smart Factory based on 'AI manufacturing → autonomous optimization → increased manufacturing competitiveness' by establishing a manufacturing innovation system based on ' Fourth Industrial Revolution + Smart TPM → intelligent manufacturing.

1.2 Measures to Revitalize Manufacturing Competitiveness in Smart Factories

(1) Implementation Overview

Recently, many companies have been pursuing ① the establishment of smart factories, ② the introduction of automation equipment, ③ the implementation of MES and ERP systems, and ④ the application of AI and IoT.

However, the effects on fundamental competitiveness improvement in actual manufacturing sites often fall short of expectations.

Chapter 2

Basic Concepts for Implementing C-TPM Activities

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2.1 C-TPM Activities for Smart Factories in Plant Industries

(1) Overview of Implementation

C-TPM (Competitive Total Productivity Management) for smart factories in plant industries is a smart manufacturing innovation management system designed to establish world-class manufacturing competitiveness.

It achieves this by eliminating all forms of loss across production, equipment, quality, energy, safety, and the environment through the application of AI, IoT, Big Data, digital twins, and advanced management practices within continuous-process sectors such as oil refining, petrochemicals, steel, power generation, cement, paper, food, and biotechnology.

(2) The Fundamental Meaning of C-TPM

C-TPM goes beyond equipment maintenance-focused TPM; it is a comprehensive productivity innovation initiative that maximizes manufacturing competitiveness by achieving integrated innovations across ① productivity, ② quality, ③ cost, ④ delivery, ⑤ safety, ⑥ environment, and ⑦ energy.

(3) Characteristics of Plant Industries and the Necessity of C-TPM

1) Characteristics of Plant Industries

① Continuous Production: Real-time control and optimization of production processes without interruption, enabled by IoT, AI, and big data.

② Large-scale Facilities: Refers to "smart infrastructure" that autonomously optimizes itself through the integration of AI and data, going beyond the concept of simple production tools.

③ High Energy Consumption: An inherent characteristic of the shift toward digital plant industries, requiring the constant operation of massive data centers and communication networks to support advanced digital infrastructure (IoT, AI, big data, etc.).

④ High-risk Processes: A paradigm that maximizes safety and efficiency by automating and introducing intelligence into tasks performed in hazardous or dangerous environments where human access is difficult, utilizing AI and IoT technologies.

⑤ Long-duration Operation: Refers to a state where production processes run continuously, 24 hours a day, without interruption.

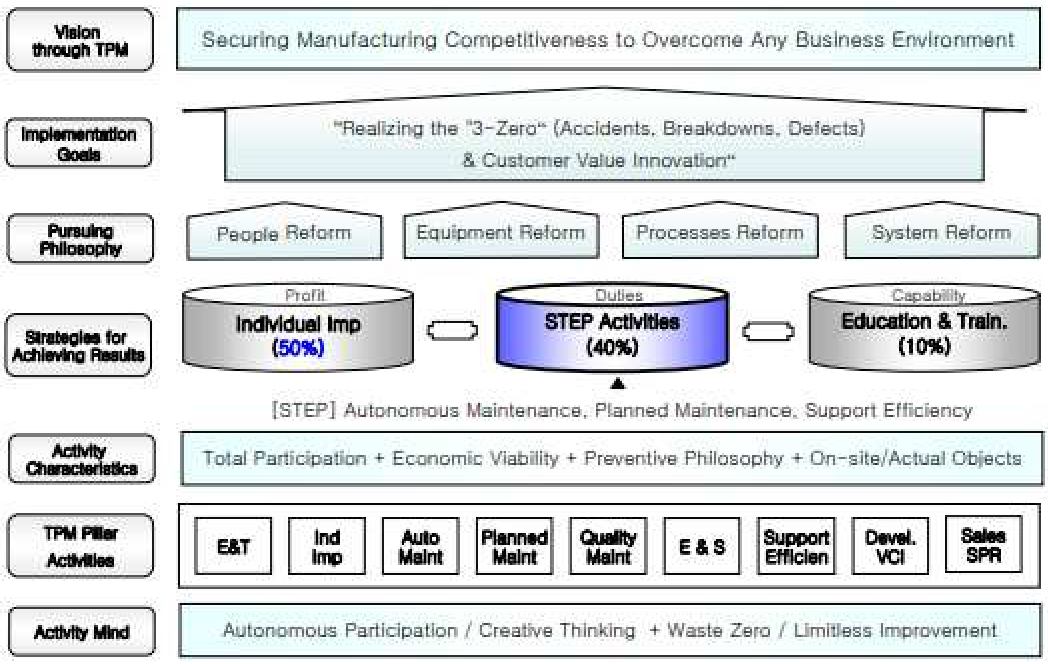
2) Impact of Issues

① Equipment failure: Massive losses

② Process instability: Reduced yield

③ Energy loss: Increased costs

④ Safety accidents: Production stoppage



[Figure 2.1] Establishing C-TPM Innovation Strategies for Manufacturing Companies [Case Study: Mid-sized Enterprise]

(4) Core Objectives of C-TPM

① Maximizing Productivity: Raising equipment utilization rates and resource efficiency to their theoretical limits through the convergence of digital, physical, and biological technologies, alongside hyper-connectivity and hyper-intelligence.

② Improving Overall Equipment Effectiveness (OEE): Maximizing production equipment utilization, preventing equipment failures, and minimizing energy and resource waste thereby cutting costs and maximizing profitability by leveraging technologies such as IoT, AI, and digital twins.

③ Improving Yield: Minimizing defect rates and maximizing mass production efficiency through the integration of digital technologies and physical manufacturing processes (smart factories).

④ Cost Reduction: Moving beyond simple cost-cutting to a paradigm that eliminates waste by optimizing processes based on data and hyper-connectivity.

⑤ Energy Conservation (EMS): Reducing costs and carbon emissions by optimizing production processes and maximizing energy efficiency through the use of AI, IoT, and big data.

⑥ Strengthening Process Safety (PSM): Predicting accidents in advance and fundamentally preventing worker injuries through the use of IoT and AI.

(5) C-TPM Core Activity Framework

① Individual Improvement: Eliminates the 16 major losses hindering production efficiency and the 8 major losses impeding the Overall Plant Effectiveness (OPE) of process-type facilities.

② Autonomous Maintenance: Refers to an intelligent production paradigm where machinery diagnoses its own condition and prevents breakdowns using IoT sensors and AI.

③ Planned Maintenance: An intelligent maintenance strategy that predicts and prevents equipment failures in advance by utilizing IoT sensors, AI, and big data.

④ Quality Maintenance: A core strategy that maintains optimal production quality and stability by using IoT and AI to detect equipment anomalies in real-time and prevent defects before they occur.

⑤ Energy Innovation: Involves using IoT and AI technologies to intelligently optimize the entire process of energy generation, distribution, and consumption.

⑥ Safety & Environment: Safety, Health, and Environment (SHE) and ESG represent core indicators of sustainable management based on digital technologies (IoT, AI, big data), extending beyond the simple productivity improvements sought in traditional plant industries (such as oil refining, chemicals, and steel).

(6) Differences between Conventional TPM and C-TPM

Category	Conventional TPM	C-TPM
Focus	Equipment maintenance	Manufacturing competitiveness
Scope of activities	Equipment-centric	Company-wide integration
Operational approach	Experience-based	Data-driven
Maintenance method	Preventive maintenance	Predictive maintenance
Goal	Reduction of breakdowns	Enhancement of competitiveness

(7) Characteristics of Smart Factory-style C-TPM

① IoT Monitoring: Real-time monitoring

② AI Prediction: Failure prediction

③ Digital Twin: Virtual process, ④ Big Data: Pattern analysis

⑤ Cloud Integration: Integrated management

(8) Key Features of Production Innovation

① OEE Improvement: Overall Equipment Effectiveness

② Yield Improvement: Yield

③ Flow Optimization: Process Improvement

④ Bottleneck Removal: Bottleneck Improvement

(9) Key Features Centered on Equipment Innovation

① Condition Monitoring, ② Predictive Maintenance

③ Remaining Life Prediction, ④ AI Diagnosis

(10) Key Features Focused on Process Optimization

① APC: Stands for Advanced Process Control.

② AI Control: Goes beyond simple mechanical automation; it refers to a system where AI learns from vast amounts of data and makes autonomous decisions to diagnose, predict, and optimize the entire process in real time.

③ Yield Optimization: A core intelligent process optimization technology that utilizes AI, IoT, and big data to minimize defects in the production process and maximize the ratio of high-quality products.

④ Process Stabilization: Refers to a state where production variability is minimized and zero defects and maximum efficiency are achieved by utilizing AI and real-time data to control and optimize the process in real time.

(11) Energy and Environment-Focused Features

① EMS: An EMS (Energy Management System) is an intelligent, integrated control system that incorporates ICT (Information and Communication Technology) to monitor and optimize energy production, consumption, and conversion processes in real time, thereby maximizing energy efficiency and reducing carbon emissions.

② Carbon Reduction: Beyond simple environmental protection, this signifies "hyper-efficient sustainability" achieved through the convergence of digital technology and energy systems.

③ Utility Optimization: This refers to minimizing waste and maximizing eco-friendly value by creating a hyper-connected, intelligent system powered by AI and IoT that manages the entire lifecycle of energy and environmental resources from production to consumption.

④ ESG Activities: This refers to achieving carbon emission reductions and eco-friendly energy efficiency improvements by leveraging digital technologies such as AI and IoT.

(12) Safety-Centric Features

① PSM: Process Safety Management (PSM) is a comprehensive safety management system that employers must implement to prevent major industrial accidents such as fires, explosions, or leaks at facilities that manufacture, handle, or store hazardous substances. Under the Occupational Safety and Health Act, workplaces operating hazardous facilities are required to prepare and undergo a review of a process safety report.

② Hazard Monitoring: This refers to a hyper-intelligent monitoring system that utilizes digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), and big data to measure, analyze, and predict hazards in industrial and daily settings in real-time, thereby ensuring safety without human intervention.

③ AI Hazard Prediction: This refers to a core technology that enables AI to detect and prepare for accidents or potential hazards in advance by leveraging vast amounts of data.

④ Smart Alarm: Going beyond simple warnings, this refers to an intelligent safety management system that utilizes IoT, big data, and AI to predict hazards proactively, analyze situations in real-time, and respond autonomously.

(13) C-TPM KPI System

① OEE: Overall Equipment Effectiveness, ② Yield: Yield rate

③ MTBF: Reliability indicator, ④ Energy Usage: Energy consumption

⑤ Carbon: Carbon emissions, ⑥ Safety Index: Safety-related indicator

(14) Future Development Directions

① Autonomous Plant: A facility that integrates AI, IoT, and big data, enabling plant equipment to assess situations and manage operations and controls independently, without direct human intervention.

② AI Factory: An intelligent factory that implements "hyper-intelligence" and "hyper-connectivity" within the manufacturing environment.

③ Self-healing: An intelligent, autonomous technology that utilizes AI and IoT to enable systems, devices, and software to diagnose errors, identify defects, and restore themselves to a normal state without human intervention.

④ Carbon Neutrality: A sustainable future development strategy aimed at achieving "net-zero" emissions by minimizing greenhouse gas emissions while maximizing absorption.

(15) Key Quantitative Implementation Targets

The core of C-TPM (Competitive Total Productive Management) aimed at enhancing manufacturing competitiveness through smart factories in plant industries lies in establishing a framework of "Competitive Manufacturing: AI + IoT + Productivity + Optimization."

In essence, the key objective is to secure world-class manufacturing competitiveness grounded in C-TPM, Industry 4.0, and autonomous manufacturing by integrating and operating productivity, equipment, quality, energy, and safety/environmental innovations based on AI.

Chapter 3

Activities to Establish the Basic Framework for C-TPM Implementation

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(13) Goal Deployment (Cascade, Drill-down) System

① Company Goals: Company-wide KPIs

② Divisional Goals: Divisional KPIs (R&D, Materials, Production, Maintenance, Logistics, Sales, etc.)

③ Team Goals: Team KPIs, ④ Individual Goals: Individual KPIs

(14) Key Factors for Successful Goal Setting

① BM Accuracy: Rationality in setting hierarchical KPI targets based on clear calculation criteria

② Realism: Achievable targets

③ Phased Approach: Driving continuous improvement combining maintenance and enhancement through a step-by-step process

④ Real-time Management: Monitoring and managing data in real-time using smart technologies such as IoT and AI

⑤ AI Analysis: Utilized for setting KPI targets

(15) Summary of Key Implementation Strategies

The approach of establishing annual targets based on C-TPM fundamental policies and the BM (current status) represents a phased manufacturing innovation framework structured around the progression of "Current Status → Target Achievement → Improvement Execution → Innovation."

In essence, the core objective is to secure smart manufacturing competitiveness founded on manufacturing excellence, productivity, and sustainability by systematically executing the following steps: ① analyzing the current status (BM), ② identifying issues, ③ setting annual KPI targets, ④ managing smart factory objectives, and ⑤ aligning with ESG goals.

3.6 C-TPM Overlapping Small-Group System with Full Participation

(1) Overview of Implementation

The core elements of C-TPM (Competitiveness-Total Productive Management) are: ① Total Participation, ② Autonomous Improvement, ③ Horizontal & Vertical Linkage, and ④ Field-based Innovation.

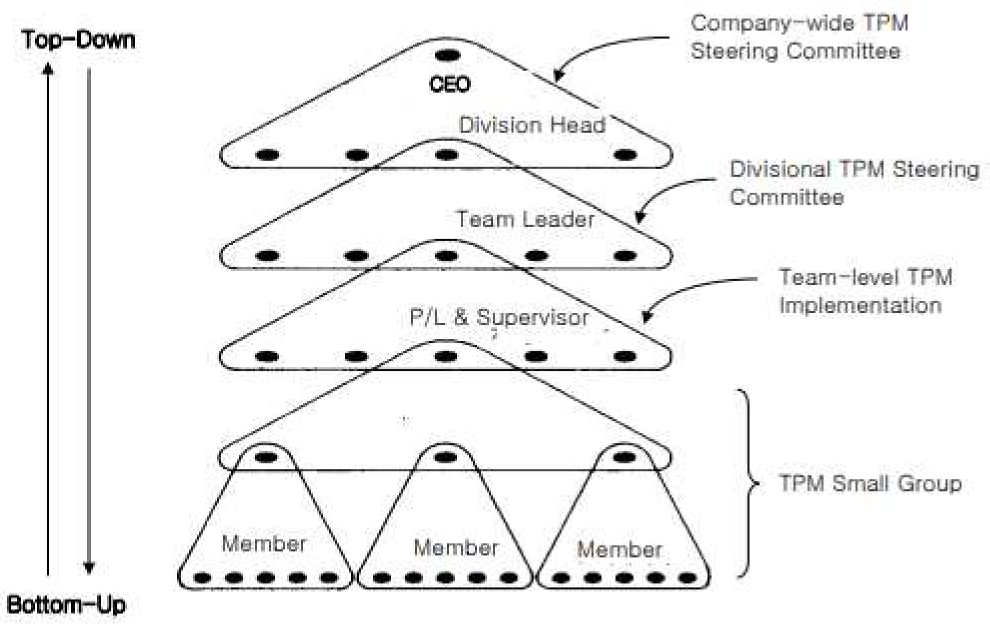
In the era of smart factories, in particular, areas such as ① production, ② quality, ③ maintenance, ④ logistics, ⑤ safety, and ⑥ AI/digital technologies are organically interconnected; therefore, organizational operations that facilitate connections across different departments and hierarchical levels are crucial.

Accordingly, C-TPM employs an "overlapping small-group system with vertical linkages" to ensure that ① top management, ② middle management, ③ supervisors, and ④ frontline workers all participate in innovation activities as part of a unified, interconnected chain.

(2) Definition of the Vertical Linkage-Type Small Group

A vertical linkage-type small group[1)] is a hierarchical innovation organization in which each level connects with ① higher-level organizations, ② lower-level organizations, and ③ units in other sectors to share common goals and carry out improvement activities.

In other words, it is a structure where connections flow from top to bottom, while improvements are communicated from bottom to top.



[Figure 3.2] Example of Overlapping Small-Group Organizational Operation

(3) Why is a vertically linked organizational structure necessary?

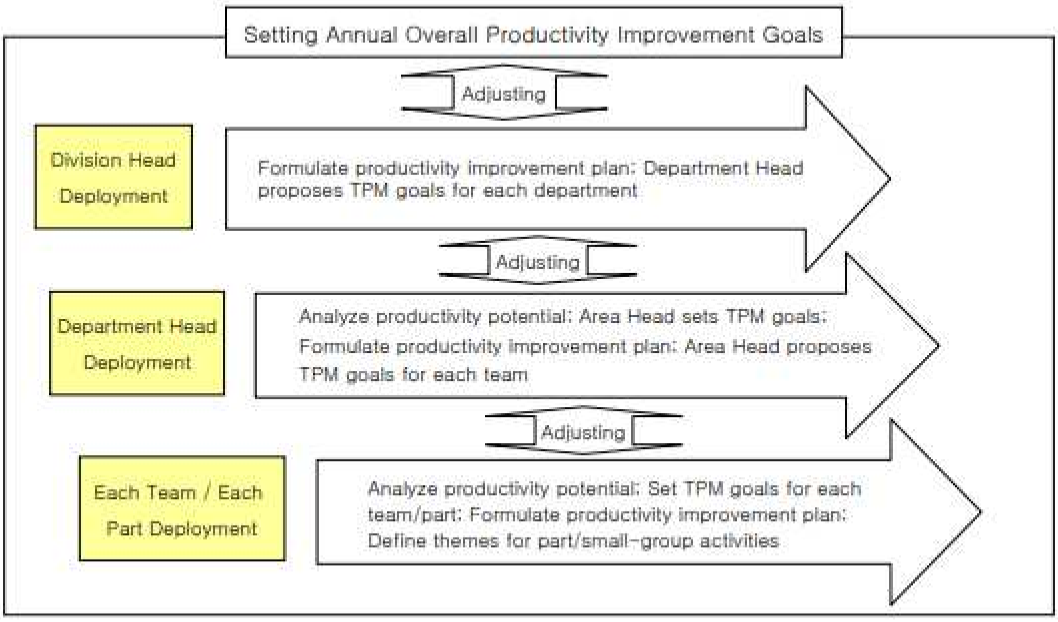
① Goal Alignment: Need for clear linkage between upper- and lower-level goals through goal deployment

② Enhanced Communication: Need for two-way dialogue (back-and-forth exchange) across all levels (vertical and horizontal)

③ Rapid Problem Solving: Direct participation and guidance-based problem solving

④ Field-focused Innovation: Activities prioritizing the actual workplace, actual objects, and actual conditions and emphasizing thoroughness and attention to detail

⑤ Culture of Continuous Improvement: Securing manufacturing competitiveness through the sustained pursuit of both "maintenance" and "improvement"



[Figure 3.3] Example of goal deployment dialogue (catch-ball) across organizational levels

(4) Issues with Existing Organizational Operations

① Departmental Fragmentation: Presence of the "silo effect."

② Vertical Disconnect: Presence of a "vertical gap."

③ Failure to Incorporate Field Feedback: Lack of input from the actual worksite; reliance on one-way, top-down directives.

④ Superficial Activities: Initiatives are often one-off events rather than part of a process for continuous improvement.

⑤ Lack of Collaboration: A critical need exists for cross-departmental and cross-hierarchical collaboration to effectively resolve complex problems.

(5) Principles of a Vertical Linkage-Based Organizational Structure

① Universal Participation: Involvement across all departments and hierarchical levels

② Hierarchical Linkage: Use of overlapping small groups to connect upper and lower levels

③ Cross-Functional Collaboration: Utilization of a matrix organizational structure

④ Shop-Floor Focus: Organizational operations prioritized to drive change at the actual worksite

⑤ Autonomous Operation: A shop-floor-centric approach where workers go beyond merely following instructions to become active agents who independently assess and improve the status of equipment and processes

(6) Organizational Structure and Roles

① Steering Committee: Policies and guidelines

② Specialized Subcommittees: Technical support

③ Team-based Structure: Innovation by team

④ Line Small Groups: On-site improvements

⑤ TFT (Task Force Team): Temporary organization for resolving specific issues

(7) Vertical Linkage and Operational Mechanism

① Deployment of Management Policy: Top-down (President → Division Head → Team Leader → Individual)

② Proposal of On-site Issues: Bottom-up (Individual → Team Leader → Division Head → President)

③ Consultation on Improvements: Cross-functional Meetings (Ad-hoc operation of CFTs)

④ Performance Sharing: KPI Review (Improvement → Cost reduction/Productivity increase/High value-added/Sales growth → Profit)

⑤ Standardization: Standardizing improvement results is crucial for continuous improvement activities, which combine maintenance and improvement.

(8) Role Structure by Hierarchical Level

① Top Management: Vision and Policy

② Middle Management: Coordination and Management

③ Supervisors: Execution and Guidance

④ Operators/Workers: Improvement and Implementation

(9) Field-Oriented Small-Group C-TPM Activities

① Autonomous Maintenance (Production Staff): Step-based autonomous maintenance for production equipment

② Autonomous Maintenance (Utility): Step-based autonomous maintenance for utility equipment

③ Autonomous Maintenance (Environmental Facilities): Autonomous maintenance for environmental facilities (e.g., wastewater treatment)

④ Planned Maintenance (Maintenance Staff): Step-based planned maintenance in maintenance workshops

⑤ Support Efficiency (Logistics/Testing Equipment): Autonomous maintenance for support functions (logistics, testing, etc.)

⑥ Development VCI (R&D/Design Staff): Step-based Development VCI activities in R&D departments

⑦ Sales SPR (Sales/Service Staff): Field-based Sales SPR activities for sales and service personnel

⑧ Individual Improvement (All Departments): Thematic improvements and resolution of on-site inefficiencies

⑨ Education & Training (All Departments): Staff training, maintenance fundamentals training, smart technology training, etc.

(10) Smart Factory Integrated Operations

① IoT: Real-time data acquisition, ② AI: Predictive Maintenance (PdM)

③ MES: Production operations via Manufacturing Execution System

④ Dashboard: KPI status management

⑤ Digital Twin: Simulation in a virtual environment

(11) Overlapping Sub-group Meeting Operation System

① Daily Meeting: Routine management

② Weekly Meeting: Weekly improvement progress

③ Monthly Meeting: Review of performance and achievement against KPI targets

④ Management Meeting: Strategic review regarding manufacturing competitiveness (C-TPM, cost reduction, profit growth, etc.)

(12) Performance Measurement and Management System

① Participation Rate: Participation rate by team/small group relative to the total; activity rate by C-TPM category

② Number of Improvements: Number of thematic improvements; number of rectifications/improvements regarding inefficiencies or defects

③ Productivity: Productivity per person; productivity per hour; value-added productivity

④ Quality: Defect rate by line/product; inspection failure rate

⑤ Safety, Health, and Environment: Accident indicators related to industrial safety and health regulations

(13) Key Factors for Successful Operation

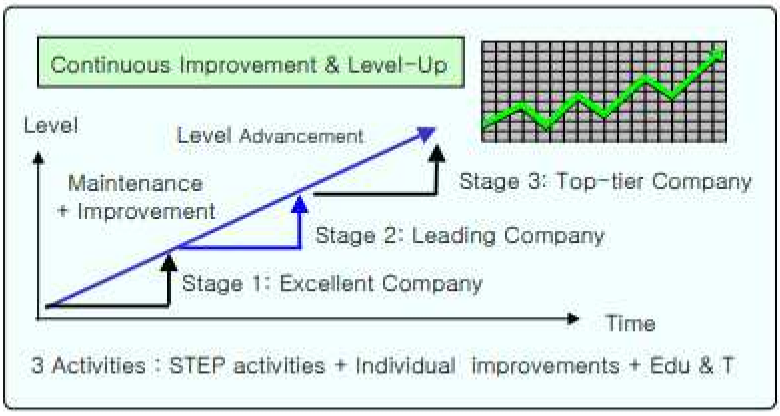
① Leadership: Exercising leadership, presenting a vision, and clearly articulating policies

② Communication: Two-way communication across all levels and departments

③ On-site Engagement: Participation from all divisions (production, R&D, sales, support, etc.) and organizational management focused on transforming the shop floor

④ Data-driven Approach: KPI management utilizing smart technologies

⑤ Sustained Operation: Achieving high growth by driving continuous improvement based on a "maintain-and-improve" approach



[Figure 3.4] Enhancing manufacturing competitiveness through "maintain-and- improve" continuous improvement

(14) Expected Effects

① Organizational Revitalization:

ⓐ Transparent communication, ⓑ Field-led innovation

ⓒ Fostering a sense of ownership

② Productivity Improvement:

ⓐ Increased Units Per Hour (UPH), ⓑ Minimized resource waste

ⓒ Improved work productivity

ⓓ Reduced losses hindering production efficiency

③ Quality Innovation: Zero defects, reduced failure costs

④ Cost Reduction: Increased cost savings

⑤ Smart Innovation: Promotion of Digital Transformation (DX)

(15) Summary of Key Implementation Aspects

The C-TPM operating system, characterized by company-wide participation and a "vertical linkage" small-group structure, is an integrated, enterprise-wide innovation framework based on a combination of top-down, bottom-up, and cross-functional approaches.

In essence, the core objective is to secure smart manufacturing competitiveness driven by a cycle of "participation across all departments and levels → continuous improvement → smart factory realization" by linking top management, middle management, supervisors, and frontline workers through vertical connections to collaboratively engage in activities such as goal sharing, problem-solving, continuous improvement, and "Smart Innovation."

3.7 C-TPM Implementation Organization and Operational Methods

(1) Implementation Overview

C-TPM (Competitive Total Productivity Management) is not an improvement activity limited to a specific department; rather, it is a company-wide innovation initiative involving all sectors, including production, quality, equipment, technology, logistics, purchasing, R&D, and administration.

Therefore, successful C-TPM implementation requires establishing a clear organizational structure, defining specific roles and responsibilities at each level, and instituting a systematic operational framework.

In particular, for C-TPM in the era of smart factories, it is crucial to establish a data-driven decision-making system by integrating digital innovation capabilities into the existing TPM organizational structure.

(2) Purpose of Establishing the C-TPM Implementation Organization

① Aligning management policy with shop-floor activities: Linking management strategies with improvement activities on the shop floor.

② Establishing a company-wide participation system: Promoting inter-departmental collaboration.

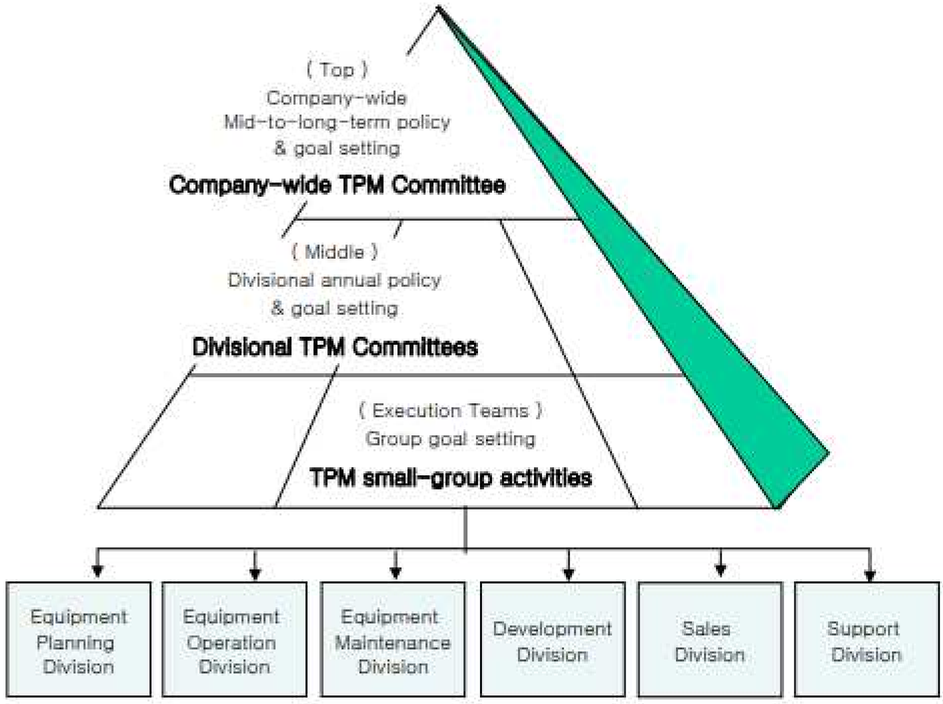
③ Ensuring the sustainability of improvement activities: Building a system for continuous innovation rather than one-off efforts.

④ Maximizing performance outcomes: Managing improvement results quantitatively.

(3) C-TPM Implementation Organization Structure

A typical C-TPM implementation organization is structured as follows:

Top Management → Steering Committee → Implementation Secretariat → Specialized Subcommittees → Implementation Teams → Implementation Groups (Small Groups)



[Figure 3.5] Example of TPM Implementation Organization

Implementation Organization	Composition	Functions
Company-wide TPM Steering Committee	• Chairperson: President • Secretary: Head of Innovation • Division Members: Division Heads, Sector Heads	• Determine company-wide TPM policies and strategies • TPM Diagnosis and guidance
Company-wide TPM Secretariat	• Factory Innovation Team • performs the role of Secretariat	• Establish and manage the comprehensive TPM Master Plan • TPM Diagnosis and guidance • Measures to revitalize company-wide TPM
Sector TPM Steering Committee	• Chairperson: Sector Head • Secretary: Senior Team Leader	• Determine sector-specific TPM policies and strategies • Sector TPM Diagnosis and guidance
Sector TPM Secretariat	• Designated team within the sector • Sector TPM Secretariat	• Manage sector TPM Master Plan • TPM Diagnosis and guidance • Measures to revitalize sector TPM
TPM Steering Committee / Subcommittee	• Chairperson: Senior Team Leader • Secretary: Senior TPM Leader • Members: Senior Team Leaders	• Review subcommittee mid-to-long-term plans • Establish subcommittee activity plans • Manage and coordinate subcommittee activities
Team TPM Execution Committee	• Execution Committee Chair: Team Leader • Members: Project/Task Leaders, Shop Floor Supervisors	• Review team TPM implementation • TPM Diagnosis and guidance for small groups
TPM Small Group	• Group Leader • Group Members	• Carry out small-group TPM activities • Self-Diagnosis of small-group TPM activities

[Figure 3.6] Example of TPM Implementation Organization and Functions (Large Enterprise)

Implementation Organization	Composition	Functions
Company-wide TPM Committee	• Chairperson: President • Coordinator: Plant Manager • Members: Production Team Leader, etc.	• Deliberation on TPM activity policies and goal setting • Deliberation and resolution of issues regarding TPM implementation • Review of performance reports and other necessary matters
TPM Secretariat	• Secretariat Head: Innovation Team Leader • Working-level Staff: 1 person	• Establishment and management of the comprehensive TPM Master Plan • Guidance and management of implementation by area • TPM Diagnosis and guidance • Formulation of plans to revitalize company-wide TPM
Factory TPM Committee	• Chairperson: Plant Manager • Members: Team Leaders	• Determination of plant-level TPM implementation policies and strategies • TPM Diagnosis and guidance for teams and implementation units
TPM Leader	• 1 per team: Team Leader	• Internal guidance for team-level TPM small-group activities • Research and training on TPM activities for team-level small groups
TPM Small Group	• Group Leader: Senior member • Secretary: Senior member • Members: Assigned employees	• Execution of TPM small-group activities [KPI / Focused Improvement / Step Activities / Education & Training] • Self-Diagnosis of TPM small-group activities

[Figure 3.7] Example of TPM Implementation Organization and Functions (Mid- sized Enterprise)

(4) Organizational Structure and Roles by Level

1) Top Management (CEO)

① Key Roles:

ⓐ Declaring the C-TPM initiative, ⓑ Establishing management policy

ⓒ Setting innovation goals, ⓓ Providing resource support,

ⓔ Evaluating performance

② Key Activities:

ⓐ Kick-off declaration, ⓑ Monthly performance reviews

ⓒ Awarding best practices

③ Core Responsibility: Ultimate responsibility for the success of C-TPM

2) C-TPM Steering Committee

① Composition: Plant Manager, Division Head, Department Head, Executives

② Key Roles: Determining implementation policies, approving annual plans, evaluating performance, selecting key projects

③ Operational Cycle: Regular meetings once a month; special meetings as needed

3) Implementation Secretariat

① Composition: Permanent/specialized TPM secretariat

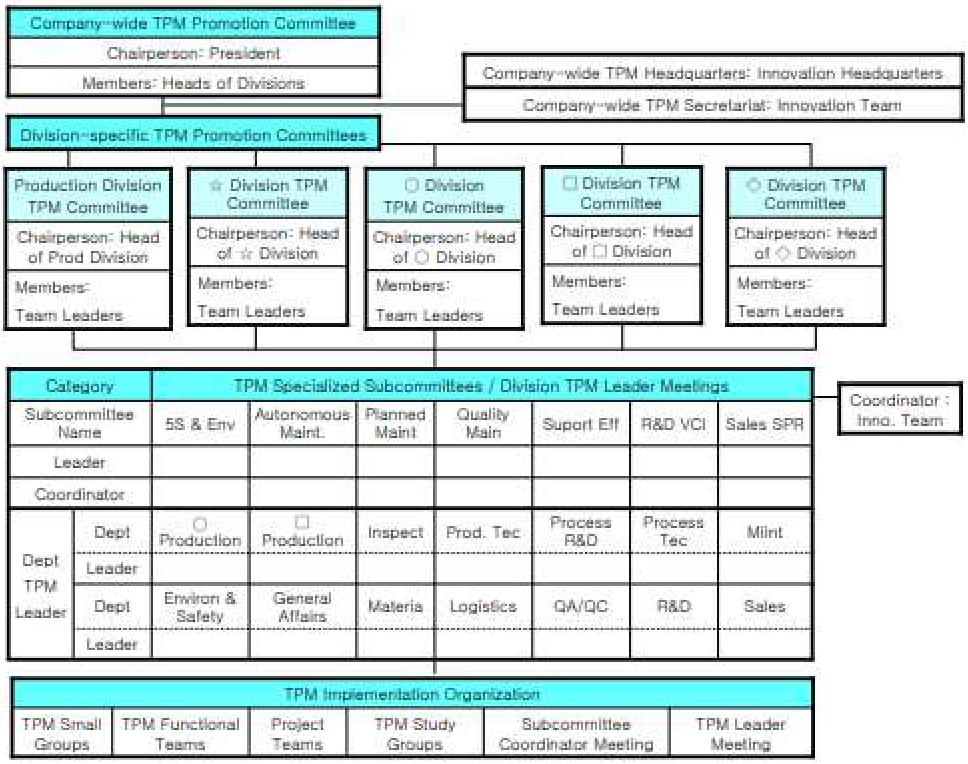
② Key Roles: Overseeing overall activities, managing training operations, tracking progress, aggregating performance data, and conducting assessments

③ Detailed Tasks: Implementation planning (establishing and supporting annual and monthly plans)

④ Training management: Managing support for training by organizational level and specialized training programs

⑤ Performance management: Managing KPIs and activity results

⑥ Audit/Review management: Staff assessments and evaluation of best practices



[Figure 3.8] Example of TPM specialized subcommittee operations

4) Specialized Subcommittees

① Purpose: To drive specialized improvement activities across different functional areas

② Representative Subcommittees and Key Roles:

ⓐ Autonomous Maintenance: Driving autonomous maintenance activities

ⓑ Planned Maintenance: Preventive and predictive maintenance

ⓒ Focused Improvement: Reducing losses

ⓓ Quality Maintenance: Quality improvement

ⓔ Education & Training: Talent development

ⓕ Safety & Environment: SHE (Safety, Health, Environment) innovation

ⓖ MP (Maintenance Prevention) & Early Management: Innovation in early-stage management (equipment, products)

ⓗ Support Efficiency: Innovation in support functions (logistics, laboratories, general affairs, etc.)

ⓘ Development VCI (Value Creation & Innovation): Value innovation

ⓙ Sales SPR (Sales Process Re-engineering): Sales innovation

ⓚ Smart Factory: Digital innovation

(5) Operation of Implementation Teams (Sub-groups)

① Concept: An execution team that carries out actual C-TPM implementation and improvement activities on the shop floor.

② Composition:

ⓐ Team Leader: Shop-floor manager/supervisor

ⓑ Team Members: Production, maintenance, and technical staff (general employees, operators, maintenance personnel, workers, etc.)

③ Size: A team size of 5~10 members is generally considered optimal.

④ Key Roles:

ⓐ Autonomous maintenance activities (production, utilities, environment): Cleaning, inspection, and improvement

ⓑ Planned maintenance (implementation team) activities: Improvement of maintenance workshops and maintenance material warehouses

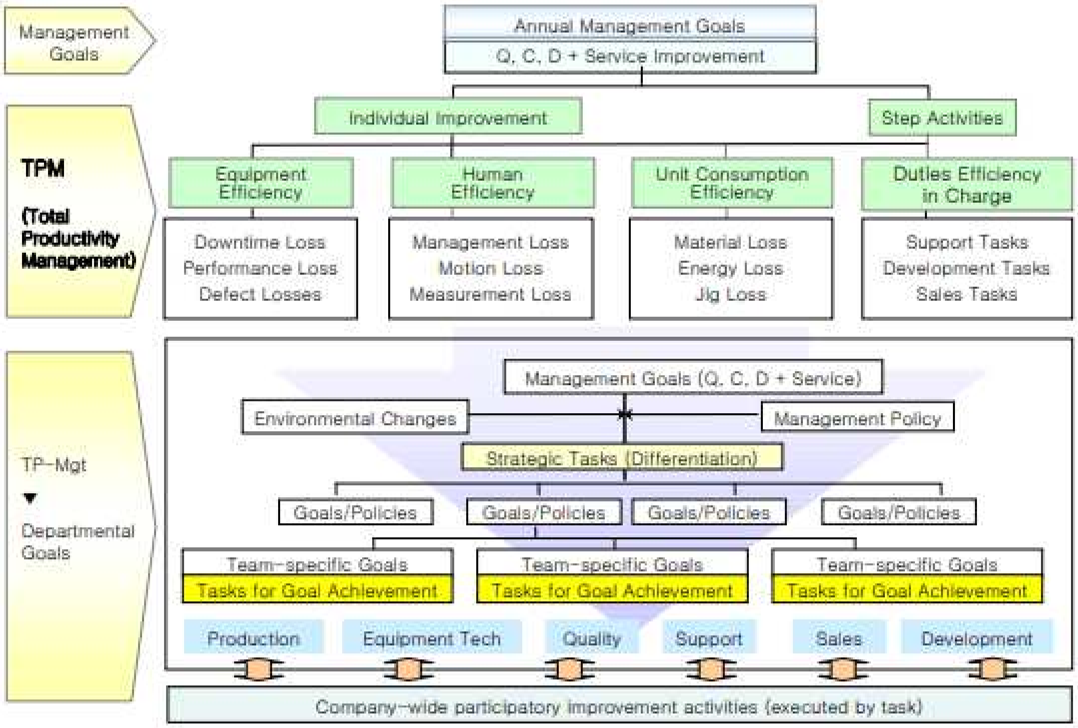
ⓒ Support efficiency activities: Organizing document archives; cleaning, inspecting, and improving assigned equipment

ⓓ Individual improvement activities: Eliminating losses, resolving issues/inefficiencies, eliminating waste, and improving productivity

(6) C-TPM Operational System

1) Policy Management System

Management policies must be cascaded so that objectives are communicated down to the shop floor following the hierarchy: Management Policy → Divisional Objectives → Team Objectives → Individual Objectives.



[Figure 3.9] Example of the Concept for Setting Objectives

<Table 3.1> Example of Setting Mid- to Long-Term TPM Objectives

Category	Item	Unit	B / M	Annual Achievement Targets (via Consulting)			Vs. B/M Improvement after 3 Years
			20XX Avg.	Year 1 Target ★	Year 2 Target	Year 3 Target	
Productivity (P)	Overall Equipment Effectiveness (OEE)	%	Current Efficiency	Based on B/M Efficiency >15% Improvement Potential	Based on Previous Year's Performance >15% Improvement Potential	Based on Previous Year's Performance >15% Improvement Potential	Based on B/M Efficiency >38.7% Improvement Potential
	Productivity per Person	Various	Current Index	10% Increase vs. B/M	10% Increase vs. Previous Year	10% Increase vs. Previous Year	33.1% Increase vs. B/M
	Number of Breakdowns	Cases/Year	Current Count	30% Decrease vs. B/M	30% Decrease vs. Previous Year	30% Decrease vs. Previous Year	65.7% Decrease vs. B/M
	Breakdown Duration	Hours/Year	Current Duration	30% Decrease vs. B/M	30% Decrease vs. Previous Year	30% Decrease vs. Previous Year	65.7% Decrease vs. B/M
	Breakdown Severity Rate	%	Current Rate	30% Decrease vs. B/M	30% Decrease vs. Previous Year	30% Decrease vs. Previous Year	65.7% Decrease vs. B/M
Q(Quality)	Defect Rate	%	Current Rate	30% Decrease vs. B/M	30% Decrease vs. Previous Year	30% Decrease vs. Previous Year	65.7% Decrease vs. B/M
C(Cost)	Unplanned Breakdown Maintenance Cost	10,000 KRW/Year	Current Amount	30% Decrease vs. B/ M	30% Decrease vs. Previous Year	Vs. Previous Year 30% ↓	65.7% ↓ vs. B/M
S(Safety)	Number of safety incidents	Cases	Current count	50% ↓ vs. B/M	50% ↓ vs. previous year	50% ↓ vs. previous year	87.5% ↓ vs. B/M
M(Morale)	Number of improvements to inefficiencies	Cases/year	Index 100	150	200	250	250% ↑ vs. B/M
	Number of problems solved	Cases/year	Index 100	130	160	190	190% ↑ vs. B/M
	Number of improvement proposals	Cases/year	Index 100	130	160	190	190% ↑ vs. B/
Remark	OEE (Overall Equipment Effectiveness) target　If the goal is a 15% increase in the "room for improvement": If the current (B/M) level is 70%, the room for improvement is 30%: 30% × 0.15 = 4.5%, resulting in an annual increase of 4.5%p.						

<Table 3.2> Example of Setting TPM Implementation Team Objectives

Category	Area	KPI Item	Unit	B / M	TARGET	Monthly Result vs. Target										Cumulative	
				1st Half of 20X3	Year 1 Target	Item	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Actual	Achievement Rate
Output Index	P	Productivity per Person	Units/Person·Month	Current Count	10% Increase vs. B/M	Tgt											
						Act											
		Overall Equipment Effectiveness (OEE)	%	Current Efficiency	Based on B/M Efficiency 15% ↑ Potential	Tgt											
						Act											
		Number of Breakdowns	Cases/Month	Current Count	30% Decrease vs. B/M	Tgt											
						Act											
		Breakdown Duration	Hours/Month	Current Time	30% Decrease vs. B/M	Tgt											
						Act											
		Breakdown Severity Rate	%	Current Rate	30% Decrease vs. B/M	Tgt											
						Act											
	Q	Process Defect Rate	%	Current Rate	50% Decrease vs. B/M	Tgt											
						Act											
		Number of Quality Claims	Cases/Month	Current Count	50% Decrease vs. B/M	Tgt											
						Act											
		Yield	%	Current Rate	Based on B/M Efficiency 10% ↑ Potential	Tgt											
						Act											
	C	Manufacturing Cost Ratio	%	Current Ratio	5% Decrease vs. B/M	Tgt											
						Act											
		Unplanned Breakdown Maintenance Cost	10,000 KRW/Month	Current Amount	30% Decrease vs. B/M	Tgt											
						Act											
		Quality Claim Cost	10,000 KRW/Month	Current Amount	30% Decrease vs. B/M	Tgt											
						Act											
	S	Number of Accidents	Cases/Month	Current Count	vs. B/M 50%↓	Tgt											
						Act											
Input Index	M	Number of inefficiencies resolved	Cases/month	Index 100	30 cases/month	Tgt											
						Act											
		Number of thematic issues resolved	Cases/month	Index 100	C-Class standard 1 case/3 months	Tgt			1			1			1		
						Act											
		Number of improvement proposals	Cases/month /team	Index 100	4 cases/month/team	Tgt	4	4	4	4	4	4	4	4	4		
						Act											
		Number of improvement sheets	Cases/month	Index 100	4 cases/month	Tgt	4	4	4	4	4	4	4	4	4		
						Act											
		Number of OPLS	Cases/month	Index 100	4 cases/month	Tgt	4	4	4	4	4	4	4	4	4		
						Act											

<Table 3.3> Matrix of TPM Implementation Organization and Contributing KPIs (Example)

TPM Metrics	Dept.	Production	Equipment Maintenance		Process	EHS		QC	Test	Process	Prod	Support					Development		Sales
		Production	Staff	Small Group	Tech	SYS	Equipment	Insp	Func Test	Development	Innovation	General Affairs	Logistics	Shipping Inspec	Purchasing	Outsourcing	Development	Design	Sales
Profit	Sales Volume																		●
	Value-Added									●							●	●	
Productivity	Production Volume	●			●														
	Productivity per Person	●			●						●								
	OEE	●	●	●	●			●	●		●								
	Equipment Breakdown	●	●	●	●			●	●										
Quality	Defect Rate	●		●	●			●	●							●			
	Quality Claims	●						●	●					●		●			
Cost	Maintenance Cost			●															
	Energy Cost	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Manufacturing Cost	●	●	●	●	○	○	○	○	●	○	○	○	○	○	○	○	○	○
Safety	Safety Indicators	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○
Environment	Environ.l Indicators	○		○	○	○	●	○	○	○	○	○	○	○	○	○	○	○	○
Morale	Number of Proposals	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Number of Themes	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	Number of OPLs	○		○			○	○	○				○	○					
	Number of Improving	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

2) Goal Management System

① Company-wide KPIs: Sales revenue, profit, cost savings, productivity, quality, safety, etc.

② Divisional KPIs: OEE, operating rate, defect rate, energy intensity, etc.

③ Individual KPIs: Number of improvements, number of suggestions, training completion rate, etc.

3) Meeting Operations and Frequency

① Steering Committee: Once a month

② Subcommittee Meetings: 1~2 times a month

③ Implementation Team Meetings: Once a week

④ Morning Briefing: Held daily

(7) Smart Factory-style Operation Method

Category	Means of Activity	Details
Data-driven Operations	Production Data	MES Integration
	Equipment Data	IoT Integration
	Quality Data	SPC Integration
	Energy Data	EMS Integration
Real-time Performance Management	Factory Dashboard	KPI status, production status, equipment status
	Activity Board	Task force activity status, improvement outcome management
AI Application	Predictive Maintenance	Predicting equipment anomalies
	Quality Prediction	Predicting defects in advance
	Production Optimization	Automated production plan optimization

(8) Success Factors for C-TPM Implementation

① Top Management Involvement: Securing strong leadership

② Company-wide Participation: Expanding involvement across all departments

③ Regular Assessments: Continuous performance improvement

④ Performance Management: KPI-driven operations

⑤ Smart Factory Integration: Digital-based innovation

(9) Role Matrix by Organization

※ ◎: Lead, ○: Support

Organizational	Planning	Implementation	Support	Evaluation
CEO	◎			◎
Steering Committee	◎			◎
Steering Secretariat	◎	○	◎	
Specialized Subcommittee	○		◎	
Steering Team		◎		
Steering Group		◎		

(10) Summary of Key Implementation Points

The C-TPM implementation organization is not merely an administrative body but an execution framework designed to drive innovation in corporate competitiveness.

Therefore, the organization should be structured as a hierarchy comprising "Top Management → Steering Committee → Implementation Secretariat → Specialized Subcommittees → Implementation Teams → Working Groups (Small Groups)" and must drive continuous competitiveness enhancement by integrating with a data-driven smart factory operating system.

3.8 Formation and Operation of C-TPM Implementation Collaboration Teams

(1) Overview of Implementation

C-TPM (Competitive Total Productivity Management) is not an activity centered on a single department but a "company-wide collaborative manufacturing innovation initiative" involving all sectors.

In the era of smart factories, in particular, areas such as ① production, ② quality, ③ maintenance, ④ equipment, ⑤ logistics, ⑥ safety, ⑦ IT/AI, and ⑧ ESG must be managed in an integrated manner; therefore, an inter-departmental collaboration system is crucial.

Chapter 6

Competitiveness Enhancement: C-TPM Activities by Element

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6.4 Autonomous Maintenance

6.4.1 Concept of Smart Factory C-TPM Autonomous Maintenance Activities

(1) Overview of Implementation

Autonomous maintenance activities within the Smart Factory C-TPM framework are shop-floor-oriented preventive maintenance tasks in which operators manage equipment themselves, detect anomalies early, and maintain equipment in optimal condition.

While equipment maintenance was traditionally centered on maintenance departments, breakdown repairs, and reactive responses, the proliferation of automated equipment, robots, AI-based production systems, and IoT-enabled machinery in smart factories has made the equipment management capabilities of shop-floor operators crucial.

Therefore, C-TPM establishes an autonomous maintenance system where operators, maintenance departments, and production engineering departments collaborate to manage equipment based on the concept of "my equipment" (taking personal ownership of the machinery).

(2) Definition of Autonomous Maintenance

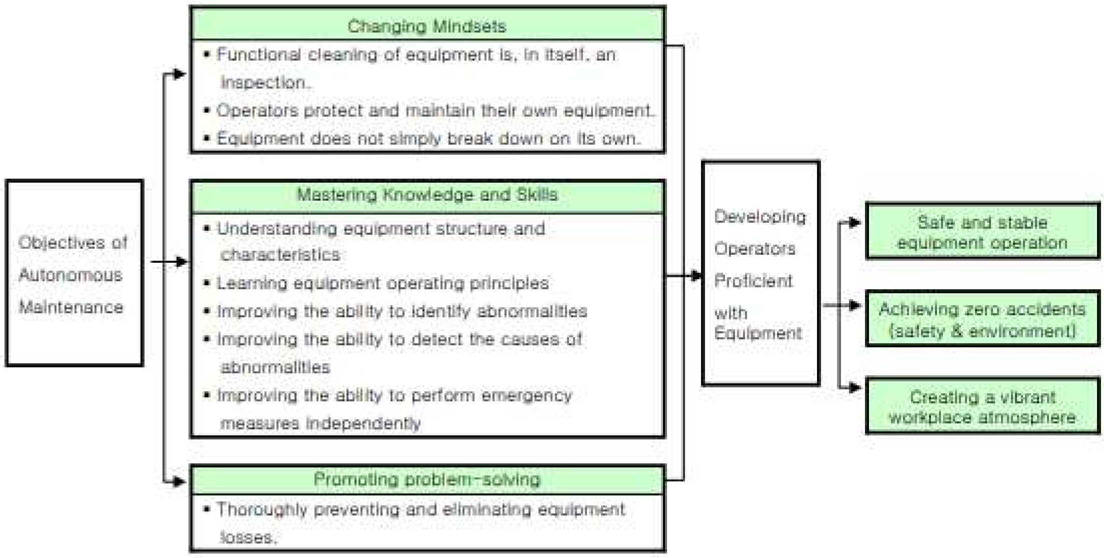
Autonomous maintenance refers to activities in which operators independently perform basic maintenance tasks such as cleaning, inspection, lubrication, tightening, and anomaly detection to maintain equipment in its optimal state.

(3) Objectives of Autonomous Maintenance Activities

① Breakdown prevention, ② Extension of equipment lifespan

③ Early detection of abnormalities, ④ Enhancement of operator skills

⑤ Production stabilization



[Figure 6.8] Example of establishing objectives for autonomous maintenance activities

(4) Characteristics of Autonomous Maintenance in Smart Factories

① Operator-centric, ② Preventive management-oriented

③ Integration with smart technologies (AI, IoT)

④ Real-time monitoring, ⑤ Data-driven

(5) Key Elements of Autonomous Maintenance Activities

① Cleaning, ② Inspection, ③ Lubrication, ④ Tightening

⑤ Abnormality detection

(6) Significance of Cleaning

In Autonomous Maintenance, cleaning is not merely about tidying up; it is an "inspection activity" aimed at detecting equipment abnormalities, deterioration, oil leaks, and wear.

(7) Concepts of Inspection Activities

① Checking vibration, ② Checking temperature, ③ Checking for oil leaks

④ Checking for noise, ⑤ Checking for wear

(8) Concepts of Smart Autonomous Maintenance Activities

① IoT condition monitoring, ② AI-based anomaly analysis

③ Mobile inspection, ④ Digital checklist, ⑤ Predictive maintenance

(9) Relationship between Autonomous Maintenance and Planned Maintenance

① Operators: Routine management

② Maintenance Department: Specialized maintenance

③ Production Engineering: Improvement activities

④ Quality Department: Quality maintenance

⑤ Safety Department: Safety management

(10) Expected Benefits of Autonomous Maintenance Activities

① Reduced breakdowns, ② Quality improvement, ③ Productivity enhancement

④ Safety reinforcement, ⑤ OEE improvement

(11) Key Success Factors for Autonomous Maintenance

① Total participation, ② Education & training (skill enhancement)

③ Standardization, ④ Visual management

⑤ Continuous improvement (pursuing improvement at each step: "maintenance + improvement")

(12) Evolution of Autonomous Maintenance Activities

① Initial stage: Cleaning-focused, ② Intermediate stage: Inspection-focused

③ Advanced stage: Prevention-focused

④ Smart stage: AI-based predictive maintenance

(13) Summary of Key Implementation Points

Smart Factory C-TPM autonomous maintenance is a core preventive maintenance system for smart manufacturing innovation, built upon the foundation of "Operator + Prevention + AI + IoT."

In essence, the core objective is to secure sustainable manufacturing competitiveness transitioning from "autonomous maintenance" to "zero breakdowns" and ultimately to "smart competitiveness" by systematically implementing: ① operator-led autonomous management, ② cleaning and inspection activities, ③ early anomaly detection, ④ smart monitoring, and ⑤ preventive equipment management.

6.4.2 Implementation of C-TPM Autonomous Maintenance for Smart Factories in Process Industries

(1) Overview of Implementation

C-TPM autonomous maintenance in process industry smart factories goes beyond simple activities such as ① cleaning, ② inspection, and ③ lubrication; it is a smart preventive maintenance initiative designed to maintain optimal equipment conditions and achieve zero breakdowns, zero defects, zero accidents, and zero losses.

Process industries, in particular, rely heavily on ① continuous production, ② large rotating equipment, ③ high-temperature and high-pressure processes, ④ automated systems, and ⑤ utility facilities; therefore, the early detection and prevention of equipment anomalies are critical.

Consequently, the C-TPM approach for smart factories employs an autonomous maintenance methodology that integrates ① operator-led autonomous management, ② AI/IoT-based condition monitoring, ③ data-driven predictive management, and ④ standardized inspection systems.

(2) Definition of the Autonomous Maintenance Implementation Methodology

The autonomous maintenance implementation methodology is a systematic approach in which operators independently perform tasks such as ① cleaning, ② inspection, ③ lubrication, ④ tightening, and ⑤ status checks.

By leveraging AI and IoT-based smart technologies, this methodology achieves ① the prevention of equipment deterioration, ② early detection of anomalies, ③ predictive maintenance, and ④ improved equipment efficiency.

(3) Key Directions for Autonomous Maintenance Implementation

① Operators: "I protect my own equipment" (Ownership)

② Prevention-oriented, ③ Data-driven, ④ Smart management (AI/IoT)

⑤ Continuous improvement

(4) Key Targets for Autonomous Maintenance in Process Industries

① Rotating equipment, ② Piping systems, ③ Utility systems

④ Instrumentation: Thermometers, pressure gauges, flow meters, etc.,

⑤ Automation equipment

(5) Key Elements of Autonomous Maintenance

① Cleaning & inspection, ② Lubrication management, ③ Fastening management

④ Deterioration management, ⑤ Abnormality management

[Photo 6.2] Examples of autonomous maintenance activities (conducted in parallel with specialized maintenance support)

(6) Key Technologies for Smart Autonomous Maintenance

① Vibration anomalies, ② Temperature anomalies, ③ Oil leakage anomalies

④ Noise anomalies, ⑤ Corrosion anomalies

(7) Key Abnormality Management Items in Process Industries

① Inspection standards, ② Lubrication standards, ③ Cleaning standards

④ Visual management, ⑤ Work standards (SOP)

(8) Key Elements of Autonomous Maintenance Standardization

① Real-time condition monitoring, ② Digital checklist, ③ AI anomaly analysis
④ Mobile responsiveness, ⑤ Integration with predictive maintenance

(9) Smart Autonomous Maintenance Operational System

① MTBF, ② MTTR, ③ OEE (Overall Equipment Effectiveness)
④ Number of breakdowns, ⑤ Number of anomalies detected

(10) Key Performance Indicators (KPIs) for Autonomous Maintenance

① Total participation, ② Education and training, ③ Role allocation by level
④ Use of smart technology (IoT), ⑤ Continuous improvement

(11) Key Success Factors for Autonomous Maintenance

① Breakdown reduction, ② Productivity improvement, ③ Quality improvement
④ Safety assurance, ⑤ Enhanced manufacturing competitiveness

(12) Expected Benefits of Autonomous Maintenance

① IoT sensors (condition monitoring), ② AI analysis (predictive analytics)
③ Mobile inspections, ④ Big data analysis
⑤ Digital dashboard (real-time monitoring)

(13) Summary of Key Implementation Strategies

The C-TPM autonomous maintenance methodology for smart factories in process industries is a core smart preventive maintenance system based on the integration of operators, prevention, AI, IoT, and standardization.

The core objective is to secure sustainable manufacturing competitiveness moving from inspection and prevention to prediction and zero loss by systematically implementing: ① operator-led autonomous management, ② cleaning and inspection activities, ③ standardization management, ④ smart condition monitoring, and ⑤ AI-based predictive management.

6.4.3 C-TPM Autonomous Maintenance Step Activities for Smart Factories in the Process Industry

(1) Overview of Implementation

Autonomous maintenance in the process industry refers to activities in which operators independently maintain and manage the basic conditions of equipment and process conditions, thereby ensuring equipment reliability and process stability.

While autonomous maintenance in general assembly and machining industries focuses primarily on equipment, autonomous maintenance in the process industry is characterized by the simultaneous management of both equipment and processes.

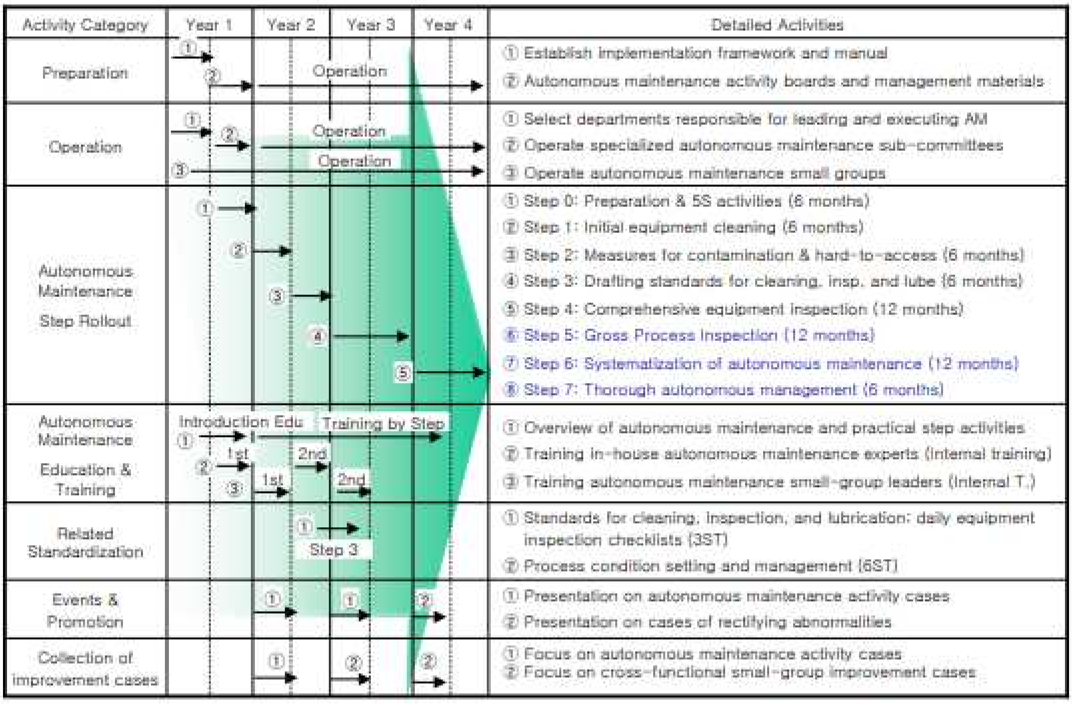
In particular, within a smart factory environment, autonomous maintenance activities are digitized and made intelligent through the use of IoT, AI, big data, and mobile inspection systems.

(2) Concept of Autonomous Maintenance Implementation in the Process Industry

The ultimate goal of autonomous maintenance in the process industry is for operators to become experts in both equipment and processes.

(3) 7-Step Autonomous Maintenance Implementation Framework

Step	Activity Name	Key Objective
Step 1	Initial Cleaning	Detecting latent defects
Step 2	Countermeasures for Sources of Contamination & Hard-to-Access Areas	Improving manageability
Step 3	Establishing Standards for Cleaning, Inspection, and Lubrication	Maintaining basic conditions
Step 4	Gross Equipment Inspection	Ensuring equipment expertise
Step 5	Gross Process Inspection	Ensuring process expertise
Step 6	Systematizing Autonomous Maintenance	Organizational institutionalization
Step 7	Autonomous Management & Smart Autonomous Maintenance	Digital advancement



[Figure 6.9] Example of a Master Plan for Autonomous Maintenance Implement- ation in the Process Industry

(4) Autonomous Maintenance: 7-Step Activities

1) Step 1. Initial Cleaning

① Objective: To discover latent defects and eliminate forced deterioration while thoroughly cleaning the equipment.

② Key activities:

ⓐ Cleaning pumps, compressors, and heat exchangers

ⓑ Cleaning piping and tanks; ⓒ Detecting oil and water leaks

ⓓ Detecting corrosion and cracks; ⓔ Detecting abnormal vibration or noise

ⓕ Attaching defect tags

③ Key focus areas:

ⓐ Cleaning is an inspection activity

ⓑ Uncover abnormalities hidden within contamination

④ Expected effects:

ⓐ Equipment cleanliness; ⓑ Discovery of latent defects

ⓒ Equipment restoration

Category	Implementation Details	In Charge		Jan.	Feb.	Mar.	Apr.	May	Jun.	In Charge
		Staff	Mem.							
Step 1 Preparation	Training on Step 1 (Initial Equipment Cleaning) Manual	●	○	••						
	Establish Step 1 (Initial Equipment Cleaning) Schedule		○	•••						
	Designate Equipment Cleaning Zones	○	●	•••						
	Prepare Cleaning Tools & Study Characteristics	○	●	•••••						
Equipment Functional Cleaning	Perform Functional Cleaning & Check for Abnormalities (by category)		●		••••••					
	Training on Cleaning Methods & Safety Precautions	●	○		•••					
Record Abnormalities	Identify Abnormalities (Defects, Sources, Hard-to-Access Areas) & List Findings					••••••				
Implement Corrective Actions	Implement Minor Repairs & Maintenance (In-house) ▶ Mechanical Elements & Drive Systems ▶ Lubrication & Pneumatic/Hydraulic Systems ▶ Electrical & Instrumentation Systems	○	●				••••••	••••••		
	Request Major Repairs & Maintenance (Maint. Dept.)	○	●				••••••	••••••		
	Document Minor Improvement Cases (C/F Sheets)		○				••••••	••••••		
Visual Management	Implement Visual Management for Equipment ▶ Alignment Marks, Gauge Ranges, Flow Meter Ranges ▶ Valve Open/Close Status, Rotation Direction ▶ Color Coding (Valve Handles, Piping), Tiger Marks ▶ Various Equipment Nameplates	○	●					•••••• •••	••• •••	
Activity Board	Record Results & Countermeasures on Activity Board	○	●	•••	•••	•••	•••	•••	•••	
Act. Diagnosis	Team Leader's Step 1 Activity Diagnosis	○		△	△	△	△	△	△	

[Figure 6.10] Examples of specific activities (Step 1)

2) Step 2. Countermeasures for Sources of Contamination and Hard-to-Access Areas

① Objective: To improve sources of contamination and areas that are difficult to access for inspection and cleaning.

② Key Activities:

ⓐ Measures for sources of contamination: a) Eliminate oil leaks, b) Eliminate steam leaks, c) Eliminate dust generation, d) Prevent raw material scattering.

ⓑ Measures for hard-to-access areas: a) Install inspection windows, b) Install platforms/footing, c) Improve lighting, d) Secure safe walkways.

③ Key Focus Areas:

ⓐ Reduce the generation of contamination rather than simply reducing cleaning work.

ⓑ Make improvements to facilitate easy inspection.

⑤ Expected Benefits:

ⓐ Reduced cleaning time, ⓑ Improved inspection efficiency

ⓒ Enhanced safety

Category	Implementation Details		In Charge		Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	In Charge
			Staff	Mem.							
Step 2 Preparation	Training on Step 2 (Countermeasures for sources of contamination & hard-to-access areas) manual		●	○	••						
	Establishing the Step 2 schedule			○	•••						
Listing sources & hard-to-access areas	Listing sources of contamination and hard-to-access areas (by zone)			○	•••						
Clarifying issues	Clarifying the status of unresolved defects (major defects) from Step 1, sources of contamination, hard-to-access areas, etc. (e.g., volume of contamination generated, cleaning time for hard-to-access areas)			○		•••					
Establishing improvement plans	Establishing schedules for addressing issues (major defects, sources, hard-to-access areas)		○	●		•••					
Improvement implementation	Autonomous maintenance	Implementation after theme registration (Joint resolution items for sub-groups)	○	●			•••••	•••••	•••••	•••••	
		Routine improvements / Small-scale improvements (key individual-level items)		○			•••••	•••••	•••••	•••••	
	Resolution via request	Resolution with support following a maintenance request	○	●			•••••	•••••	•••••	•••••	
	Accumulating improvement cases	Creating Improvement OPLs (One-Point Lessons) and Improvement Sheets		○			•••••	•••••	•••••	•••••	
Maintenance education & training	TPM techniques	Conducting "Know-Why" (5 Whys) analysis	○	●				•••••	•••••	•••••	
	Maintenance function training	Training on basic on-site maintenance skills	○	●				•••••	•••••	•••••	
Activity Board	Recording results and managing countermeasure activities on the board		○	●	••	••	••	••	••	••	
Act. Diagnosis	Team leader's Diagnosis of Step 2 activities		○		△	△	△	△	△	△	

[Figure 6.11] Examples of specific activities (Step 2)

3) Step 3. Establishing Standards for Cleaning, Inspection, and Lubrication

① Objective: To standardize criteria enabling operators to manage equipment autonomously.

② Key Activities:

ⓐ Cleaning standards: Cleaning areas, Cleaning methods, Cleaning frequency

ⓑ Inspection standards: Inspection items, Management criteria, Allowable ranges

ⓒ Lubrication standards: Lubricant type, Lubrication quantity, Lubrication frequency

ⓓ Operation standards: Pressure, Temperature, Flow rate, Liquid level

③ Smart Factory Application:

ⓐ QR code-based inspection, ⓑ Mobile checksheets

ⓒ Electronic standard operating procedures (SOPs)

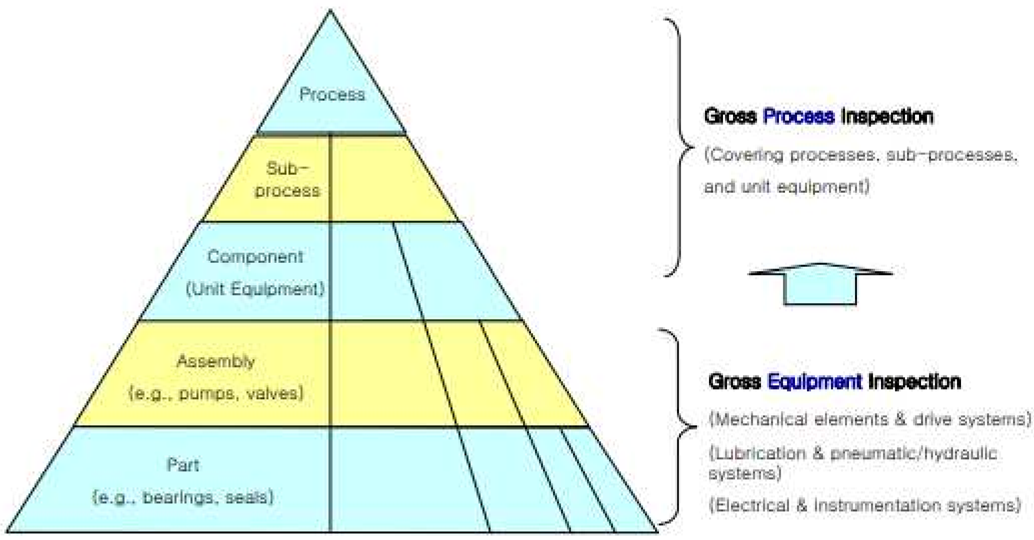
④ Expected Effects:

ⓐ Maintenance of basic conditions, ⓑ Prevention of missed inspections

ⓒ Standardization of work

Category	Implementation Details	In Charge		Jan.	Feb.	Mar.	Apr.	May	Jun.	In Charge
		Staff	Mem.							
Step 3 Preparation	Training on Step 3 (Drafting standards for cleaning, inspection, and lubrication)	●	○	••						
	Establishing the schedule for Step 3		○	•••						
Initial Item Listing	Listing cleaning, inspection, and lubrication points	○	●	•••						
Understanding Equipment Principles	Gathering data and understanding equipment principles (structural diagrams, cleaning/inspection/lubrication details)	○	●		••••••	•••••				
Cleaning, Lubrication, & Inspection Training	① Training on cleaning and inspection procedures ② Training on lubrication management (oil, grease) and lubrication basics ③ Training on inspection procedures (focusing on inspection points and items)	●	○			••• ••• •••				
Secondary Item List Refinement	Refining and updating the list of cleaning, inspection, and lubrication points	○	●			•••				
Drafting Equipment Management Standards (by category)	Drafting standards for cleaning, inspection, and lubrication; creating daily equipment inspection checklists	○	●				••••	••••••		
Execution & Addressing Issues	Carrying out tasks based on cleaning, inspection, and lubrication standards		○						••••••	
	Identifying operational issues and implementing revisions/improvements	○	●						••••••	
Activity Board	Recording performance data and managing countermeasures on the activity board	○	●	••	••	••	••	••	••	
Act. Diagnosis	Team leader's Diagnosis of Step 3 activities	○		△	△	△	△	△	△	

[Figure 6.12] Example of specific activity details (Step 3)



[Figure 6.13] Classification of targets for Total TPM activities

4) Step 4. Gross Equipment Inspection

① Objective: To enable operators to understand the structure, principles, and functions of the equipment and to diagnose abnormalities themselves. The "Gross Equipment Inspection" (Step 4 of Autonomous Maintenance) is a process in which operators accurately understand the equipment's structure and functions, then

Chapter 7

Measuring the Effectiveness of C-TPM for Competitiveness Enhancement

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Cost, Delivery) metrics

③ Internal Process perspective: Indicators related to P·Q·C·D·S·E (Productivity, Quality, Cost, Delivery, Safety, Environment)

④ Learning and Growth perspective: Indicators related to M (Manpower/People)

(9) Comprehensive Model for Measuring C-TPM Effectiveness in Process Industry Smart Factories

Manufacturing Competitiveness → Productivity + Quality + Cost + Delivery + Safety & Environment + Talent Development + Smart Transformation

(10) Ultimate Goal

Continuous Improvement + Data-Driven Management + Total Participation → Achieving World-Class Manufacturing Competitiveness

(11) Key Implementation Summary

The effectiveness measurement indicator system for C-TPM in plant industry smart factories must be established as an enterprise-wide KPI framework that integrates management across productivity, quality, cost, delivery, safety & environment, talent development, smart transformation, and ESG.

In particular, by establishing a hybrid performance management system that links visual management centered on activity boards with digital management centered on KPI dashboards, it is possible to objectively measure C-TPM performance outcomes and achieve continuous improvement in manufacturing competitiveness.

7.2 C-TPM Effectiveness Measurement: Calculating Overall Equipment Effectiveness (OEE)

(1) Overview of Implementation

The core objectives of C-TPM activities are to maximize equipment efficiency, improve productivity, stabilize quality, reduce costs, and secure manufacturing competitiveness.

To achieve this, manufacturing sites utilize the Overall Equipment Effectiveness

(OEE) metric to quantitatively evaluate the actual operational efficiency of equipment.

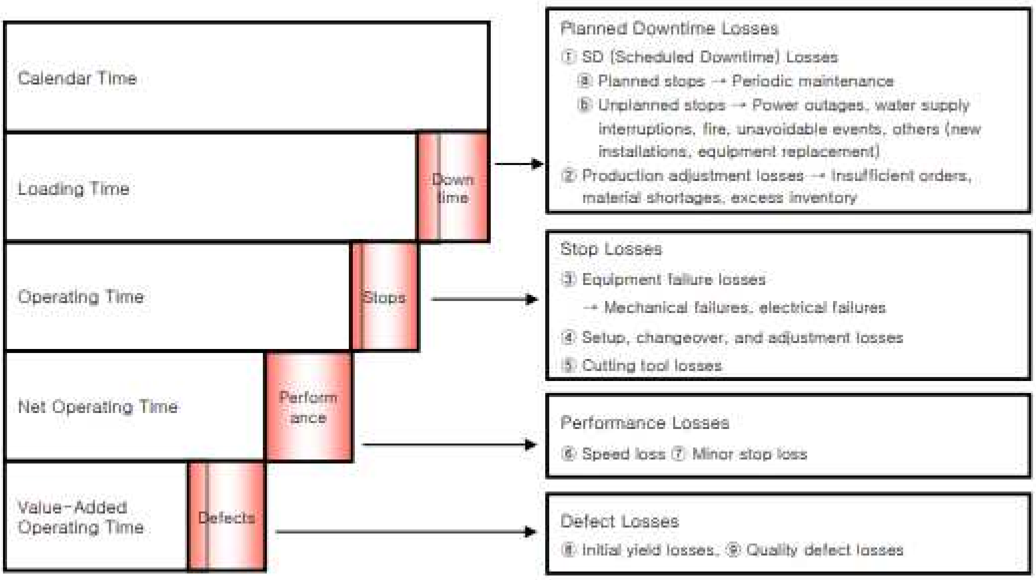
Notably, in the manufacturing sector, the methods for calculating efficiency differ depending on the equipment characteristics specifically distinguishing between traditional machining/assembly equipment and process-type equipment (used in continuous processing industries).

For traditional equipment, efficiency management focuses on individual units, whereas for process-type equipment, the focus is on production efficiency centered on continuous processes.

(2) Calculating Overall Equipment Effectiveness (OEE) for Processing-Type Equipment

The relationship between the structure of the six major losses in processing-type equipment and Overall Equipment Effectiveness (OEE) is shown in [Figure 1].

Processing-type equipment refers to equipment such as machining equipment or batch-processing equipment that does not necessarily operate continuously.



[Figure 7.1] Six Big Losses and OEE Calculation for Processing-Type Equipment

OEE is calculated by multiplying three factors: availability (time efficiency), performance efficiency (speed efficiency), and quality rate.

It serves as a comprehensive metric indicating the extent to which the equipment contributes to value-added production, taking into account its status regarding time and speed, as well as the quality of the output.

Time Availability=(Load time-Downtime)÷Load time

=Operating time÷Load time

Performance Availability

=[(Production Volume×Actual Cycle Time)÷Operating Time]×

(Theoretical Cycle Time[1]÷Actual Cycle Time)]

=(Theoretical Cycle Time×Production Volume)÷Operating Time

Quality Rate=Quantity of Good Products÷Input Quantity

Where: Quantity of Good Products=Input Quantity-(Initial Defects+Process Defects+Rework Quantity)

Overall Equipment Effectiveness (OEE)=Time Availability×Performance Availability×Quality Rate

[Figure 7.2] Six Big Losses and OEE Calculation for Processing-Type Equipment

※ Explanation:

1. Theoretical cycle time

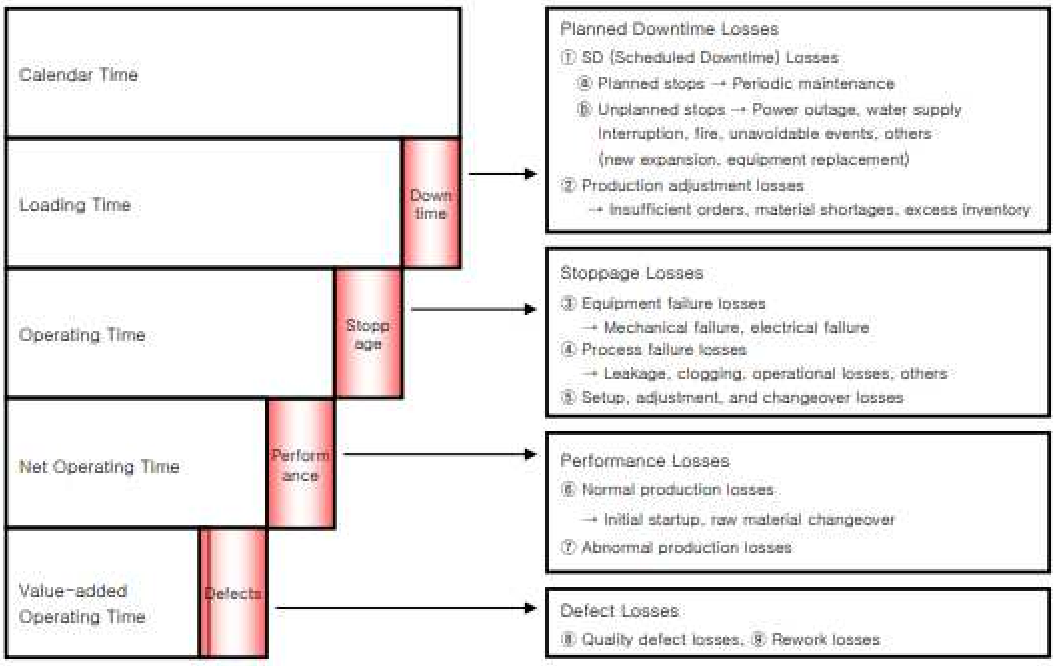
① Theoretical cycle time (min/unit) also known as standard cycle time is the reciprocal of theoretical production rate (units/min).

② Theoretical cycle time represents the shortest achievable time required to produce a single unit (units: min/unit, sec/unit, etc.).

(3) Calculation of Overall Plant Efficiency for Plant-Type Equipment

Equipment that operates continuously due to the nature of the operation is referred to as process-type equipment (e.g., chemical processing units, steelmaking facilities, etc.).

The relationship between the structure of the eight major losses and the overall plant efficiency for process-type equipment is shown in [Figure 3].



[Figure 7.3] Structure of the Eight Major Losses for Process-Type Equipment

Overall Plant Efficiency (also known as Overall Production Efficiency)

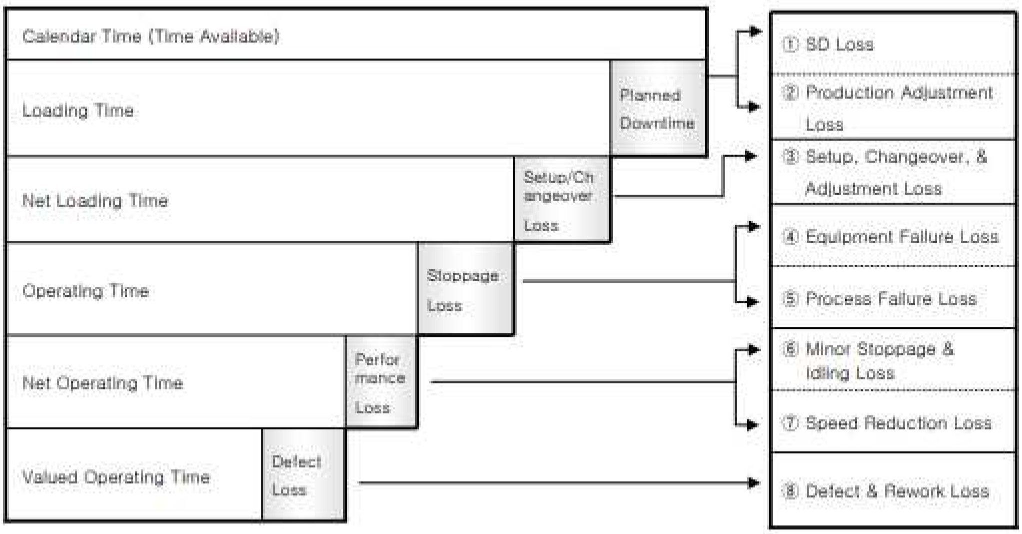
= Load Factor×Overall Equipment Efficiency

= Load Factor×Time Availability×Performance Efficiency×Quality Rate

Ch. 7

(4) C-TPM: Advanced System for Calculating Overall Equipment Effectiveness (OEE) Applicable Across All Industries

1) Structure of Time Losses Hindering Equipment Efficiency



Source: Ph.D. Dissertation by Dr. Kwon O-un (Korea University)