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Manufacturing Planning and Execution Software Interfaces

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Abstract

Process planning and manufacturing execution systems provide two major functions in a product development cycle. Industries require the systems that support these two functions to be able to integrate with other related manufacturing systems, such as design, resource planning, production scheduling, and equipment control. However, there are information barriers to the integration of commercial systems in these areas. This paper presents an activity model for manufacturing execution and a set of foundation interfaces, identified in an object model, that have been developed to cope with the problem. The interfaces are intended to be a base from which they evolve as the new technology and industrial practices emerge.

Keywords: *Interface Specification, Manufacturing Activity Models, Manufacturing Execution, Manufacturing Systems Integration, Object Modeling, Process Planning*

1. Introduction

The integration of a manufacturing execution system (MES)[1] with related manufacturing applications, such as computer-aided design (CAD), computer-aided process planning (CAPP), computer-aided manufacturing (CAM), scheduling, enterprise resource planning (ERP), and equipment control systems, is a relatively new practice. Many industries currently use a MES for managing factory floor information and activities to increase productivity and improve quality. Examples of factory floor information and activities are resource allocation, dispatching production units, quality management, operation planning, detailed scheduling, labor management, product tracking, and keeping records of product genealogy. Because CAD, CAM, CAPP, ERP, control, and scheduling systems support linked sets of activities and information flow, it is beneficial to industrial users if these manufacturing software systems can exchange data and messages (function calls) with each other in a diverse computing environment. This means that the MES has to be an integrated component of a manufacturing system.

A feasible way of meeting this industrial need is to develop a mechanism to allow software, on a variety of platforms, to exchange data and messages. One way to develop such a mechanism is to design a system of standard interfaces so that different software systems can “plug and play.” It is possible to develop such a system of interfaces using available technology in software “gluing,” also referred to as middleware. A set of foundation interfaces has been developed for manufacturing planning and execution to cope with the integration and interoperability problems. These interfaces are documented in this report.

To better understand a MES and its relationship to other manufacturing activities, this document provides the following theoretical basis: a definition of a MES, the context in which a MES performs, its functions, and fundamental interface objects of a MES. In addition to this section that introduces the foundation interfaces for manufacturing process planning and execution software integration, section 2 provides a definition of a MES, section 3 describes current methodology and technology for manufacturing software integration, and section 4 contains the interfaces and the context in which they are developed and used. Section 5 concludes the paper with a call for continued development of standard MES interfaces.

2. Manufacturing Execution System

The primary goal of a MES is to provide an information system that can be used for optimizing production activities in a manufacturing facility with the focus on quick response to changing conditions. Some subgoals of a MES are as follows:[2]

1. to improve communication inside a facility; for example, part programs can be electronically downloaded from CAM systems to machine

tools and production activities can be rescheduled to reflect unexpected machine down time or production priority changes,
2. to improve communication capability between production and other activities in a manufacturing enterprise, such as product design, process planning, resource planning, supply chain management, service and sales, and equipment control,
3. to monitor production to control operations within desired performance parameters,
4. to provide up-to-the-minute communication between the facility and facility management, and
5. to better manage production-related data, including resource data, performance data, process data, job scheduling data, equipment/device control programs, and so on.

A definition of a MES can be given as follows:

> A MES is a sytem that consists of a set of integrated software and hardware components that provide functions for managing production activities from job order launch to finished products. Using current and accurate data, a MES initiates, guides, responds to, and reports on production activities as they occur. A MES provides production activity information to other engineering and business activities in the enterprise and its supply chain via bidirectional communications.

This definition is derived from a definition given in the Manufacturing Execution Systems Association (MESA) International White Paper 6 [Ref. 3]. In the paper, only major functions in a MES are described.

3. Manufacturing Planning and Execution Technology Integration Status

Standard interfaces for a MES are necessary to solve the integration problems in a heterogeneous environment. The standard interfaces usually evolve from a series of three stages. (A related study on different maturity levels of standard interfaces is described in Mowbray and Zahavi.[4]) In the first stage, developers of a software system develop the specification of proprietary, vendor-specific interfaces. They are different from one system to another. Users/integrators have to develop translators for exchanging data between any two different systems. Consequently, the integration cost to software users is usually high. To alleviate the problem of interface incompatibility, some users and vendors join a consortium to develop a common set of interfaces which is sharable among users and vendors. This set of common interfaces is a product in the second stage. Common interfaces usually lead to some integration cost reduction. However, different consortia may develop different sets of interfaces, which are often incompatible, for the same application domain. More users and vendors realize the needs of creating standard interfaces based on consensus on the international level. Thus, the final stage is interface standards development. Users, vendors, and researchers jointly develop interface standards, which are open, neutral, and internationally accepted.

Currently, commercially available manufacturing planning systems and execution systems operate on different hardware and software platforms, and these platforms are almost all incompatible with each other. To address this incompatibility, Object Management Group's (OMG) Common Object Broker Architecture specification (CORBA)[5] specifies a mechanism for software objects to interoperate on heterogeneous, distributed computing platforms. In CORBA, a portion of an application is either a client, which requests services, or a server, which provides certain services. Between a client and a server, a software broker matches requests made by a client to services provided by a server. Clients and servers can be written in a variety of programming languages and located on different platforms in a networked computing environment. To enable CORBA-based communications, the boundaries between client and server must be specified in CORBA's Interface Definition Language (IDL). Such a specification can then be used by a compiler, in a CORBA toolkit, to generate stub and skeleton code with which to glue applications together. These stubs and skeletons provide communication functions and an Application Programming Interface (API) accessible from a high-level language such as C or C++.

The Computer Integrated Manufacturing Applications Framework (CIMF), developed at Sematech,[6] has adopted the basic strategy of managing manufacturing information using CORBA. The CIMF is designed for sharing planning and opera-

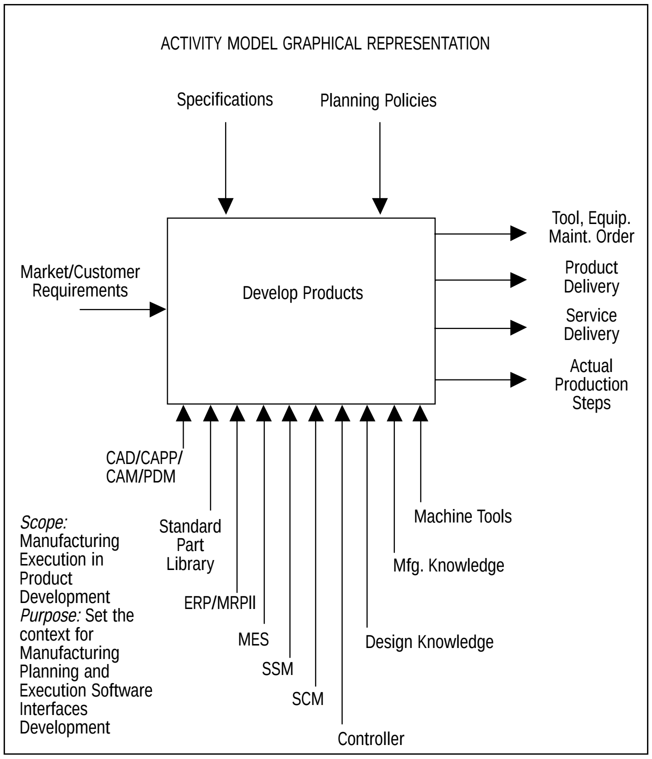

Figure 1
Activity A0

tional information on semiconductor wafer production among different control and planning software modules. The CIMF provides a set of basic entities and their relationships for semiconductor manufacturing shop-floor information management. In contrast, the content of interfaces described in this report enable general software interoperation in the mechanical product manufacturing domain.

4. Foundation Interfaces

Based on the CORBA methodology, a set of interfaces has been developed for the manufacturing planning and shop-floor execution information management for mechanical parts production. The goal of the interface design is to make the interfaces open, neutral, and extendable. The developed interfaces serve as a foundation on which more specific object interfaces can be derived and made interoperable using CORBA. Users could extend the model by specializing, overriding, and extending some of the interfaces. The interfaces in this report are in the first version. Modification and enhancement of the interfaces will take place in the future as the technology and practices evolve.

For the purpose of clarifying process planning taking place in CAPP systems and some planning/scheduling activities taking place in manufacturing execution systems, the boundary between process planning and detailed planning activities at the manufacturing execution level is given as follows. The specification process, which defines operations, their sequences, and the selection of manufacturing resources before any product is produced, is within the scope of process planning. Detailed operation planning and scheduling performed at the workstation level after the work order is issued or during the production, is within the scope of manufacturing execution.

Manufacturing Execution Activity Model

Based on the IDEF0 methodology and techniques[7] and existing high-level manufacturing process models in Harrington[8] and Bauer et al.,[9] an activity model* of product development has been developed in reference to a product realization model in Barkmeyer, ed.[10] The top-level activity is Develop Products (A0), as shown in *Figure 1*. This activity is decomposed into a series of six subactivities, as depicted in *Figure 2*. The Engineer Product and Process (A1) activity relates to designing products and generating a manufacturing process plan and alternative plans. Product design engineering includes functional requirements, conceptual design, embodiment design, detailed design, design analysis, and the specification of the bill of material. Manufacturing process engineering includes process selection, operation planning, workpiece routing, and equipment/device control program generation. This activity provides design and processing information for the downstream resource planning and manufacturing execution. The decomposition of engineer process activity, which is equivalent to process planning, can be found in the NISTIR 5808 [Ref. 11].

The Plan Enterprise Resources (A2) activity relates to analyzing parts and performing make/buy decisions for all the parts, including developing a

* An activity is indicated by its name in a box. Input data, which are transformed by the activity to the output data, are on the left side of the box with arrows pointing to the box. Control data, which are used to regulate the internal process of the activity, are above the box with arrows pointing to the box. Mechanism data, which support and enable the activity, are below the box with arrows pointing to the box. Output data are on the right side of the box with arrows pointing to the output data from the box.

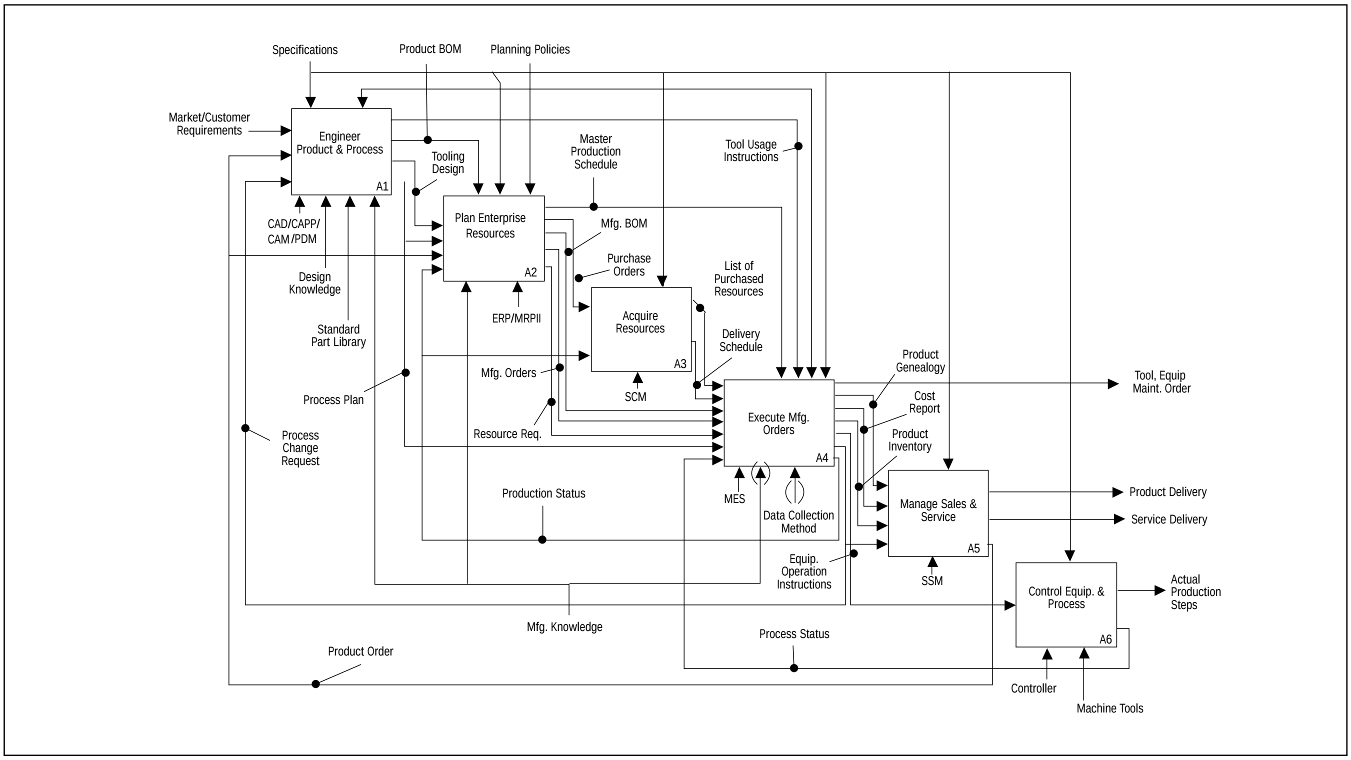

Figure 2
Activity A0—Develop Products

business plan and schedule to acquire necessary resources and/or to produce products for the market. The enterprise resources include material, finished parts, equipment, and labor skills. The enterprise resource planning function includes financial and order management, production and material planning, master production scheduling, capacity requirement planning, and job definition. It also includes business process planning and resource requirement specification. The Acquire Resources (A3) activity relates to purchase resources from suppliers to meet the production schedule, based on the resource requirement plan specified in A2. This activity is supported by supply chain management, which includes distribution, logistics, transportation management, and advanced planning. The Execute Manufacturing Orders (A4) activity relates to the manufacturing execution functions and is further decomposed to set the context for the development and use of the foundation interfaces. Based on the production plan and master schedule, A4 is to initiate, guide, respond to, and report on production activities as they occur. The Manage Sales and Services (A5) activity relates to managing sales of products and services to customers, including product delivery and receipts, product configuration, customer orders, quotes to customers, product returns, and post-sale service. Finally, the Control Equipment and Process (A6) activity relates to the use of preprogrammed instructions to control and monitor equipment motions and processes in real time. Activity A6 usually involves distributed numerical control, programmable logic control, and factory-floor data collection.

Activities A1, A2, A3, A5, and A6 are there to show their relations to A4. The Engineer Product in A1, A2, A3, A5, and A6 are out of the scope in the interfaces development. In addition to NISTIR 5808, a detailed dimensional inspection process planning model for discrete part inspection in the product development cycle is given in Feng.[12]

A4 is decomposed into the following four subactivities, as shown in *Figure 3*:

A41—Develop Operation Sequence & Detailed Schedule

Based on the production plan and the master production schedule, define, sequence, and

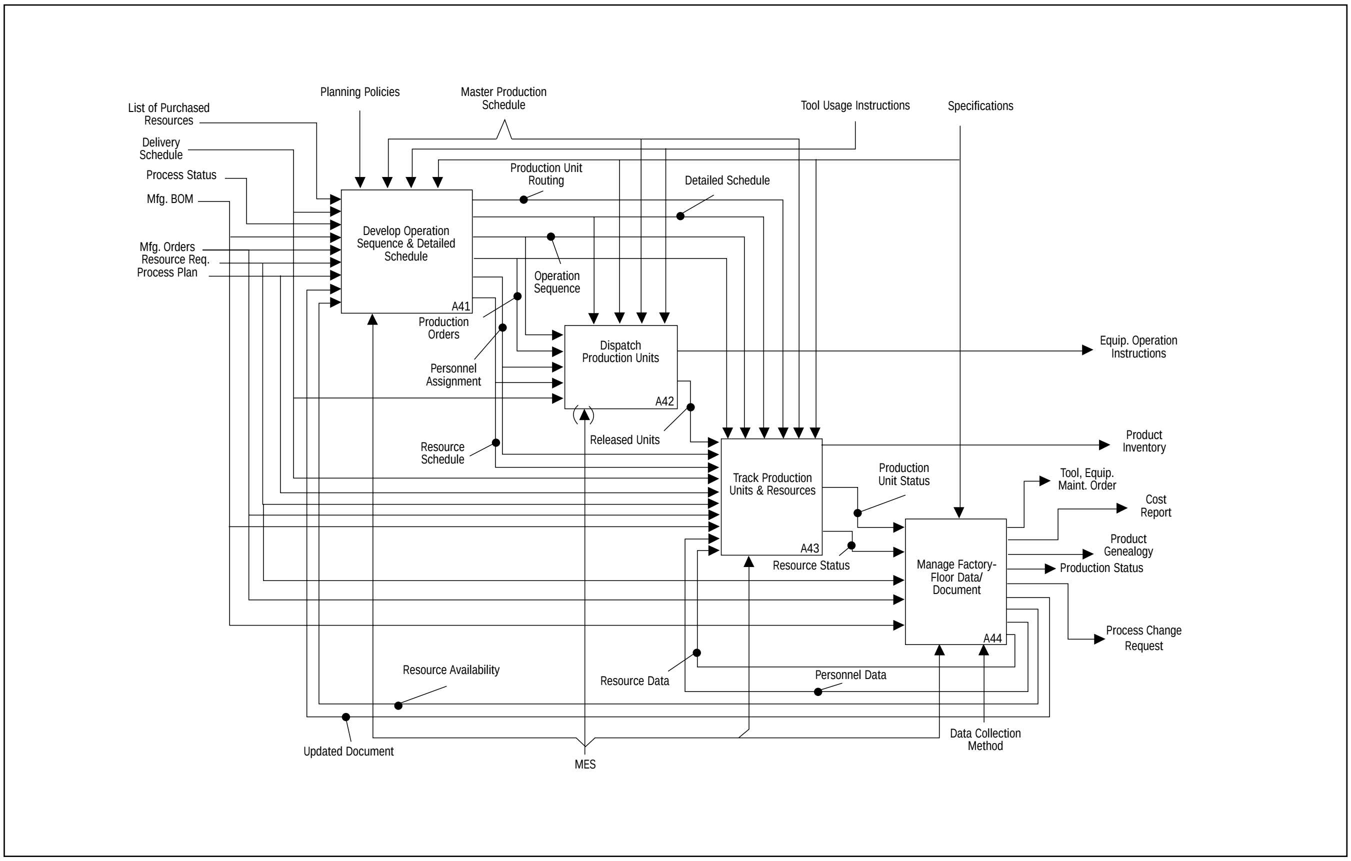

Figure 3
Activity A4—Execute Manufacturing Orders

schedule operations locally on the levels of workcell, workstation, and machine to optimize productivity, such as minimize setup time, maximize throughput, minimize idle time, minimize queue time, and adjust shift pattern when new priority is in effect.

A42—Dispatch Production Units
Determine which production unit in the queue is best processed next. The objective is to minimize the lead time and lateness.

A43—Track Production Units and Resources
Provide the information on where any production unit is at all times and its disposition. Also provide the product genealogical information, such as who worked on it, current production information, component materials by supplier, lot number, serial number, any rework, measured data, or other exceptions related to the product. In the same time, provide the status information on specified resources, such as tools, devices, machines, and stock materials, at all times.

A44—Manage Factory-Floor Data/Document
Provide hardware/software interface links to obtain mission-critical data pertinent to production activities. Collect the data from the factory and analyze them for multiple purposes, such as product throughput, quality, delivery, and equipment maintenance. Manage documents, such as cost reports, maintenance orders, inventory reports, process change requests, manuals, specifications, company policies, and so on. Control the data collection, access, and distribution. Provide versioning control of documents, such as part programs, operation instructions, manufacturing orders, detailed schedules, part drawings, engineering change notices, production unit records, records of communication from shift to shift, manuals, standards, company policies, safety regulations, and so on.

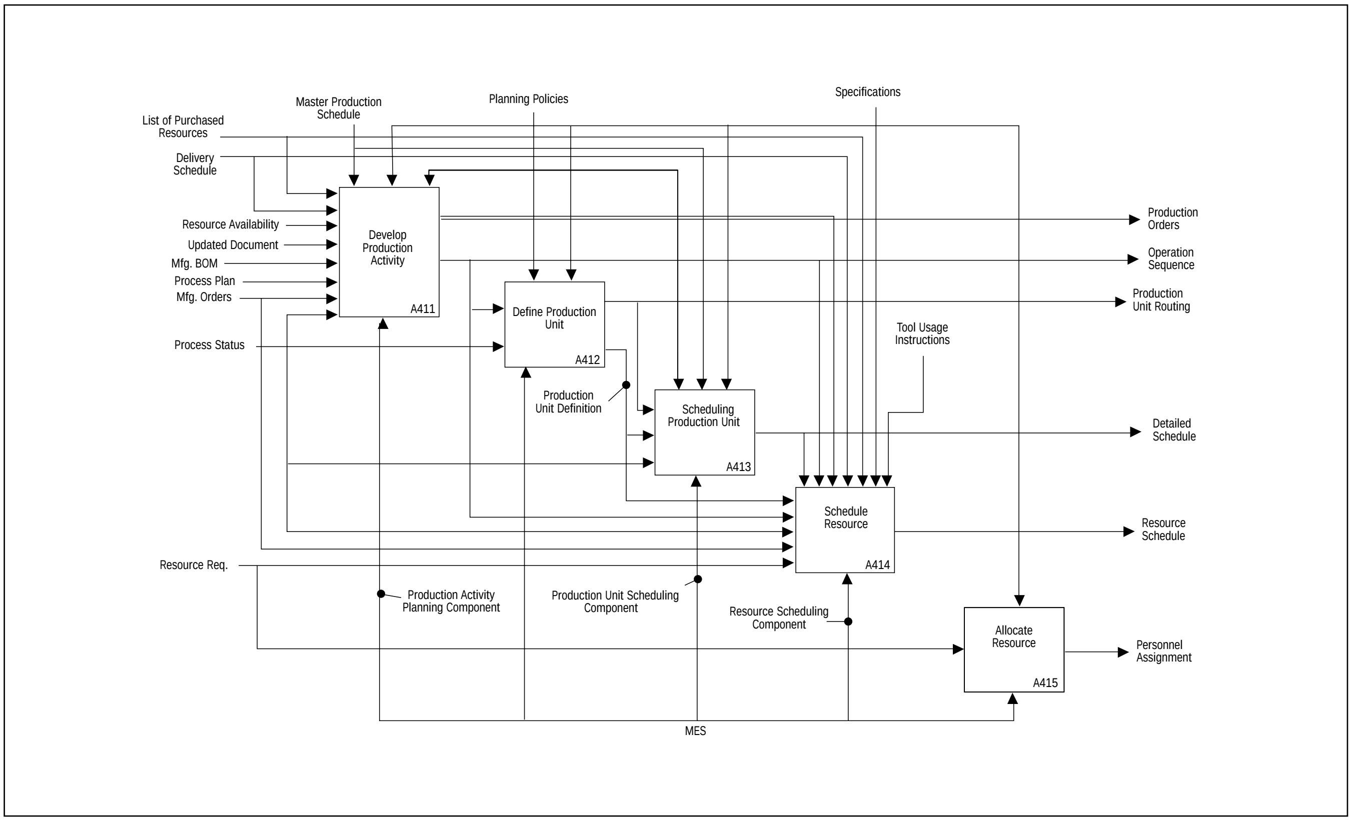

Figure 4
Activity A41—Develop Operation Sequence and Detailed Schedule

A41 is decomposed into five subactivities, as shown in *Figure 4*:

A411—Develop Production Activity
Sequence production operations based on priority, characteristics, setup changes/time, master production schedules, etc. Also, generate alternative operation sequences to recognize possible production changes, such as priority changes, machine downtime, and so on.

A412—Define Production Unit
Identify a lot or batch by decomposing or aggregating manufacturing orders. Each lot or batch is scheduled, processed, monitored, and tracked by the system as a unit.

A413—Schedule Production Unit
Add start and finish time information to a lot or batch dictated by the operation sequences. The goal is to optimize productivity and quality and to conform to the master production schedule.

A414—Schedule Resource
Add start and finish time information on each resource that is used by operation(s) in the production.

A415—Allocate Resource
Assign and make resource available to operations that need the resource before they start. Equipment must be properly set up. This activity issues an assignment that associates a type of resource and quantity of it to specific operation(s) that need(s) the resource for a specific time period.

A42 is decomposed into three subactivities, as shown in *Figure 5*:

A421—Release Resources
Based on resource allocation, release resource for the production activity in a timely manner. This activity results in physical materials, tools, etc., being moved from inventory or a storage to production cells or workstations.

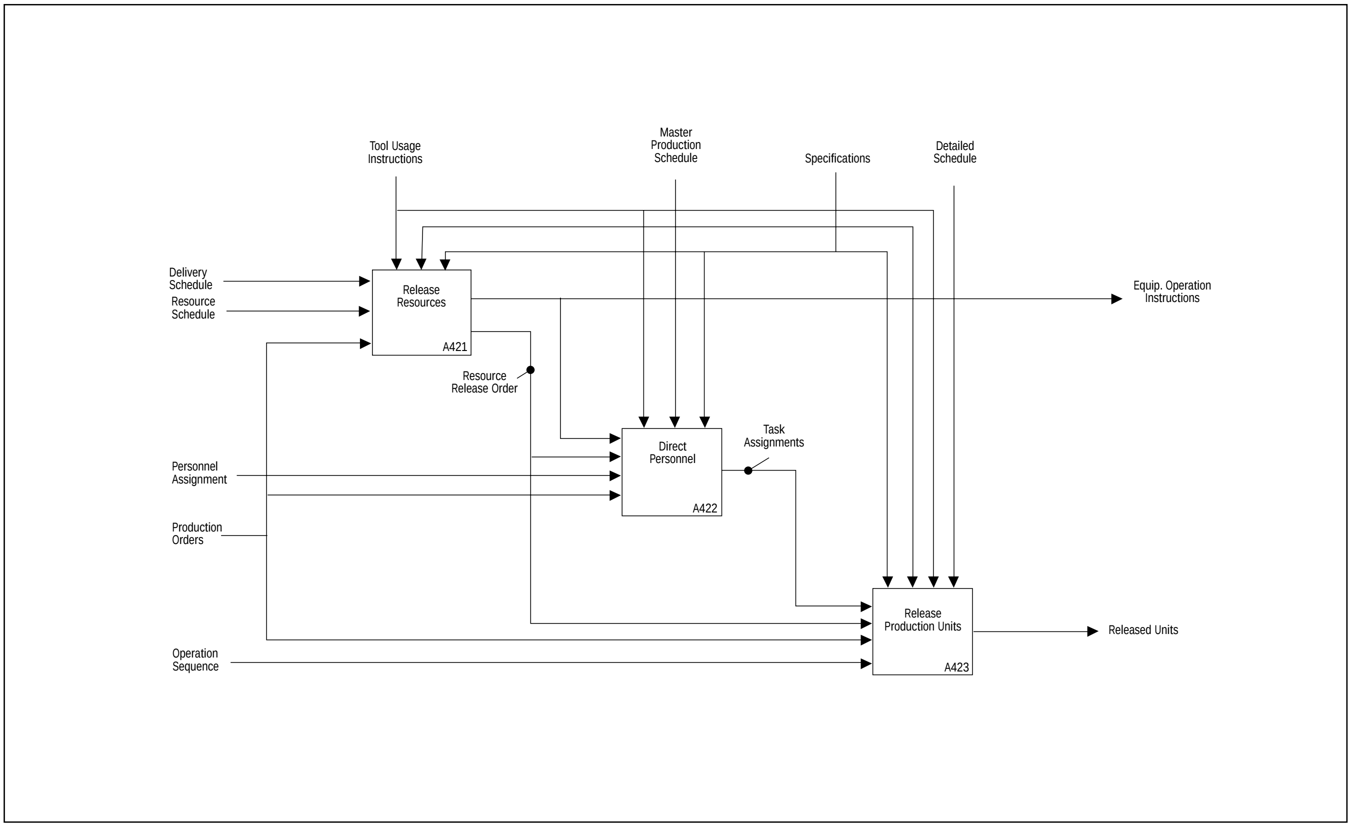

Figure 5
Activity A42—Dispatch Production Units

A422—Direct Personnel

Assign workers with adequate skills to perform specific operations according to the detailed schedule.

A423—Release Production Units

Based on the detailed schedule, release production units to workcells or workstations and initiate processing the production units.

A43 is decomposed into five subactivities, as shown in *Figure 6*:

A431—Track Resources

Follow up and monitor the status of resources. On-line track resource usability and consumption. Create a record of history of resources that are necessary to be traced.

A432—Monitor Personnel

Follow up personnel status and report the status. The report includes attendance, labor skill changes, job assignments, time performed on each assignment, and material/tool preparation time.

A433—Manage Process

Monitor a production process and make timely decisions to adjust detailed schedule and process plan when unexpected situations occur. These activities should be coordinated with the process and equipment control functions. Process management includes alarm management to make sure factory person(s) are aware of process changes that are outside acceptable tolerances. It also includes process setup and tool preparation before production units are dispatched for processing. It maintains a history of past events or problems to aide in diagnosing problems.

A434—Manage Quality

Provide timely analysis of measurements collected from products and processes to control product quality. Check the current production rate with the detailed production schedule. Identify problems in production requiring attention.

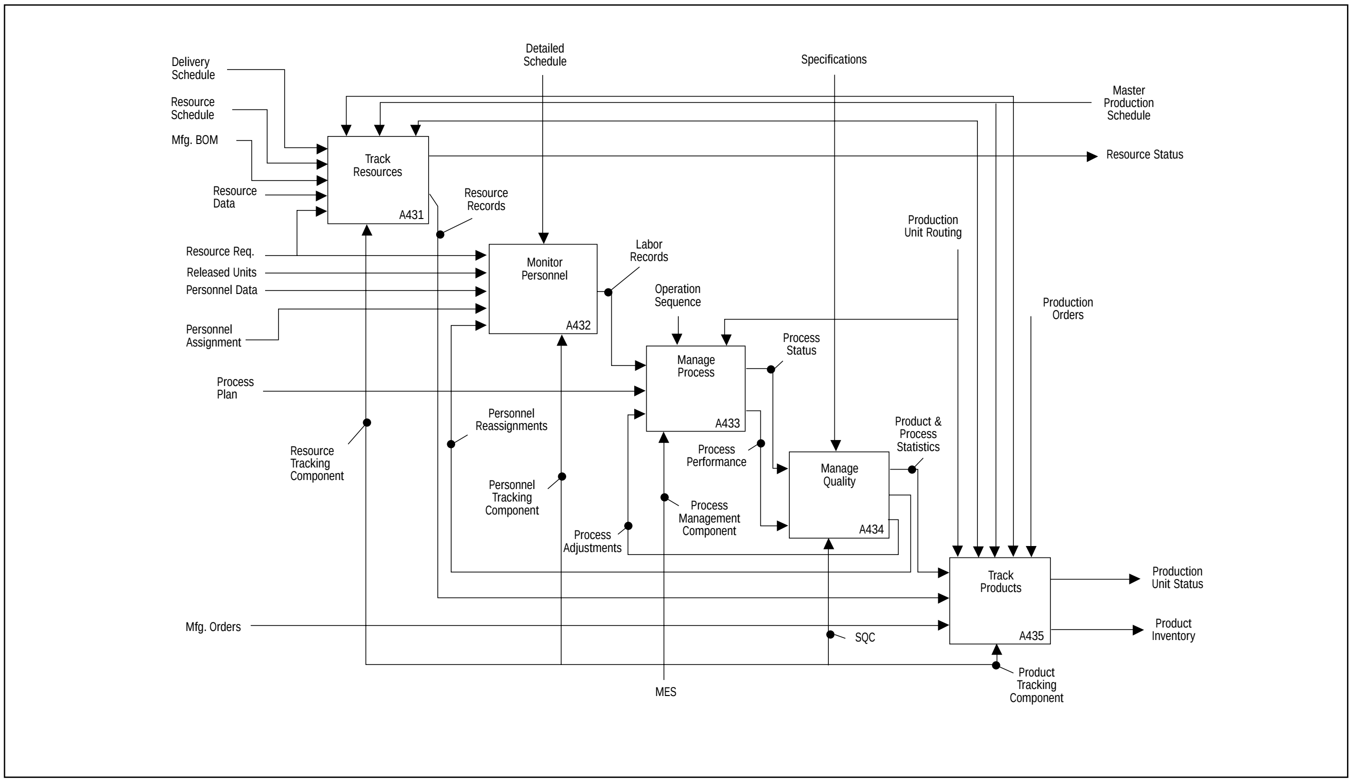

Figure 6
Activity A43—Track Production Units and Resources

Recommend proper actions to correct the problems. Make the statistics and status of products and processes visible to production/business management personnel.

A435—Track Products

Monitor the progress of production and provide up-to-the-minute report on the production status, such as the quantity of a product made, scrap rate, rework rate, and the comparison to the production schedule.

A44 is decomposed into three subactivities, as shown in *Figure 7*:

A441—Collect Production Data

Using data collection devices, acquire data by measuring and sampling workpieces, products, and production processes to support the management of product, quality, and process.

A442—Analyze Data

Using collected data and adequate algorithms, analyze the data and generate record and reports and make them available for decision making and product tracking.

A443—Manage Document

Collect (or generate), maintain, and distribute production-related documents and records to support the production, factory-floor decision making, and product traceability.

A441 is further decomposed into three subactivities, as shown in *Figure 8*:

A4411—Receive Workpiece Measurements

Using factory-floor data collection devices, acquire and collect measurements on workpieces, labor records, process conditions to monitor the process performance and product quality.

A4412—Acquire Production Unit Condition

Using data collection mechanisms, such as bar code readers or manual input devices, acquire data on the production units to determine where they are and how many units of a product have

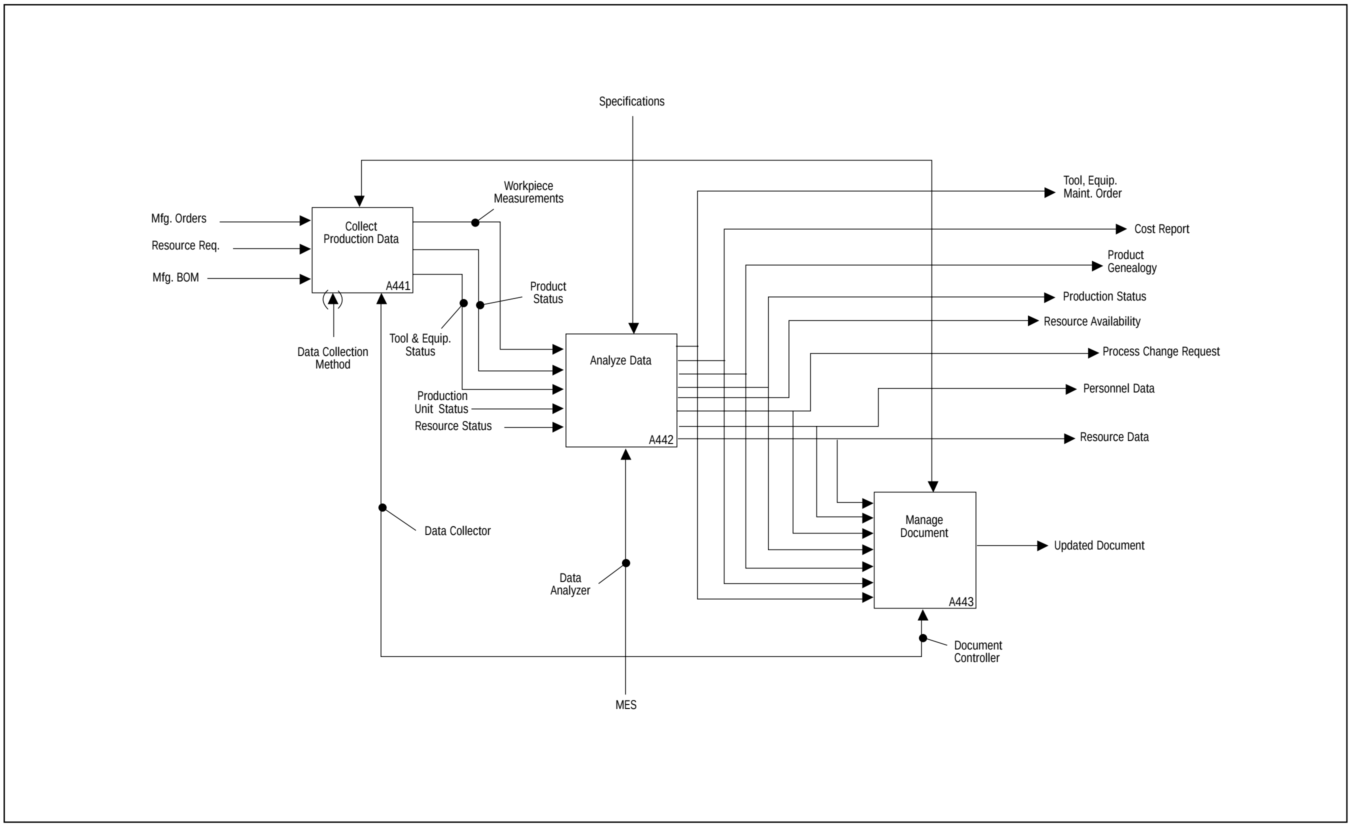

Figure 7
Activity A44—Manage Factory Floor

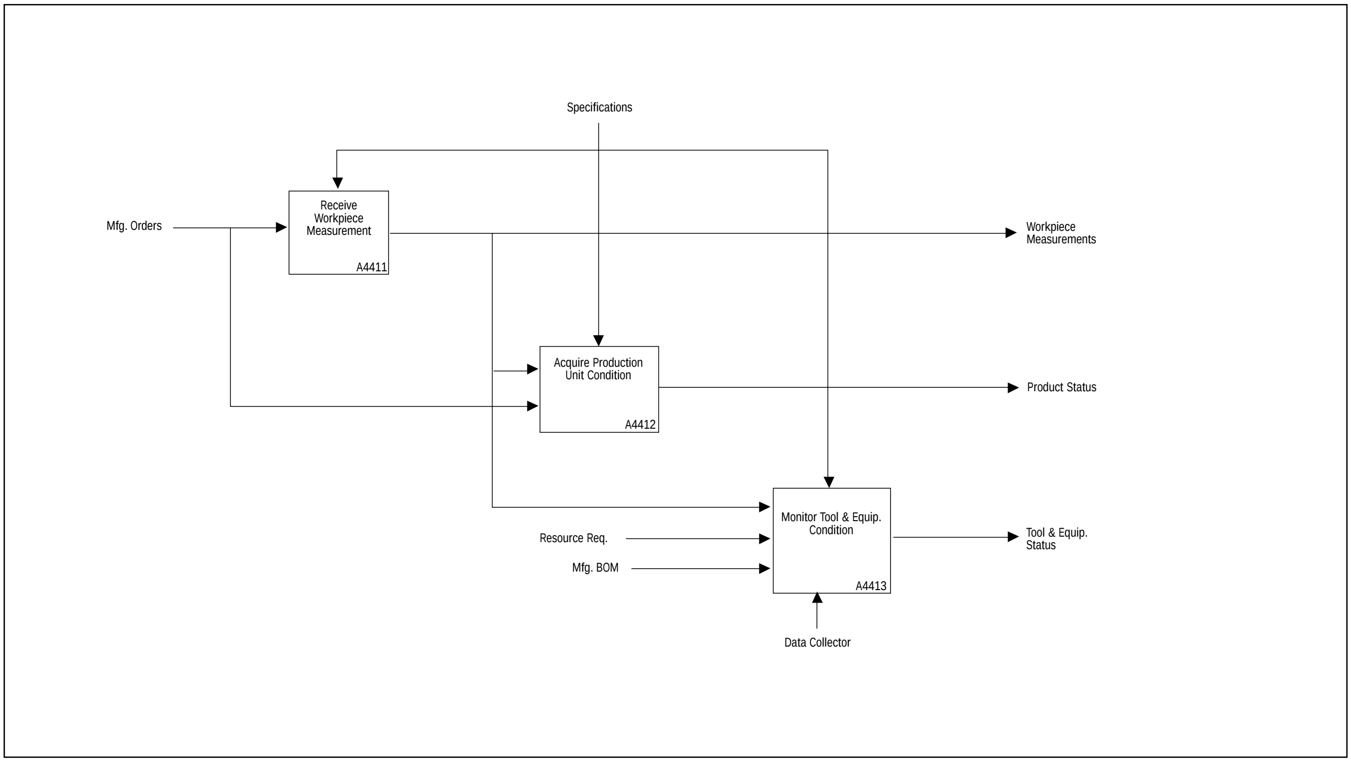

Figure 8
Activity A441—Collect Product Data

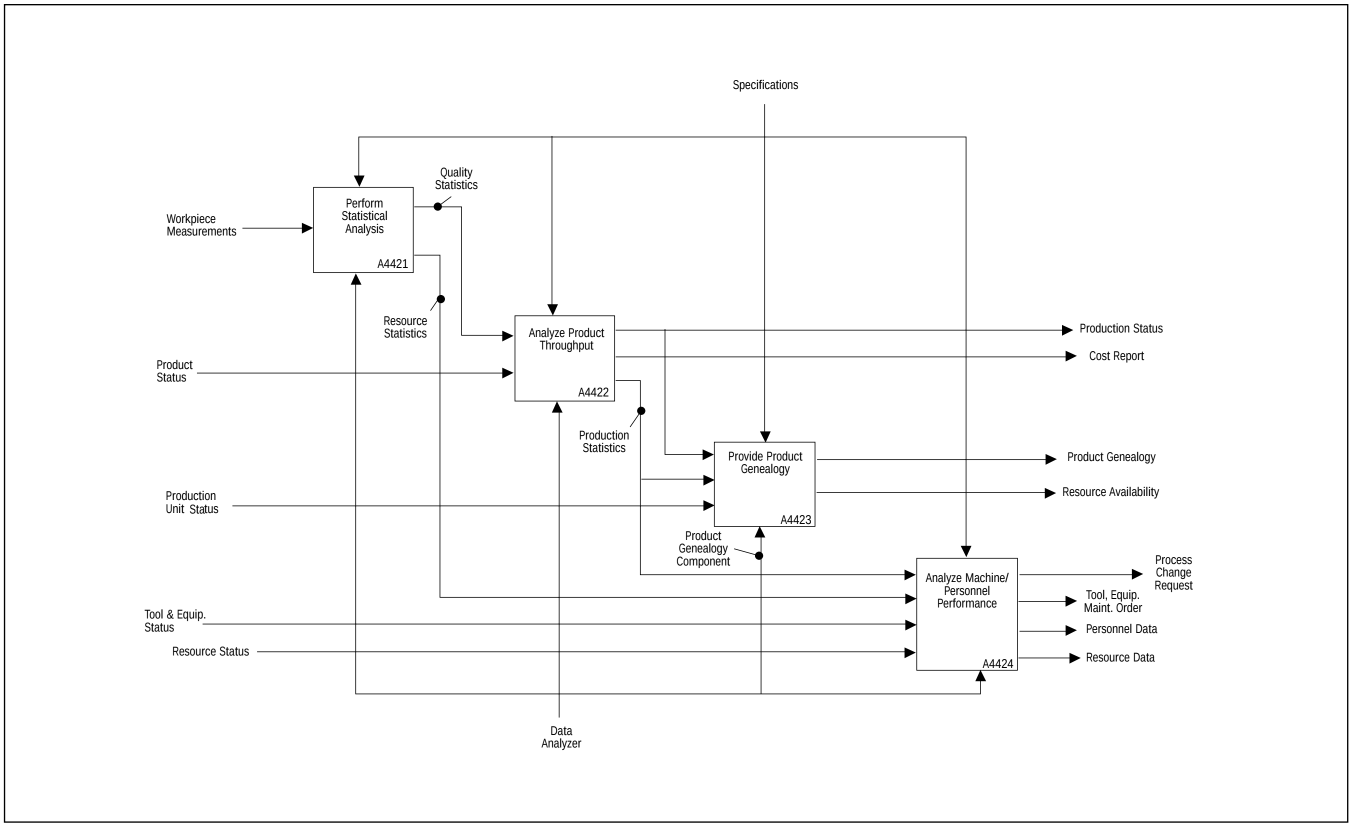

Figure 9
Activity A442—Analyze Data

been finished. Provide on-line, up-to-the-minute product status information. The data are made available and visible to production as well as business management.

A4413—Monitor Equipment Condition
Using the data measured from product and process, indicate the status of tools, devices, and machines being used in production to determine whether they are still proper to function or need adjustment or maintenance.

A442 is further decomposed into four subactivities, as shown in *Figure 9*:

A4421—Perform Statistical Analysis
Conduct statistical analysis on data collected from the shop floor for tracking process performance and ensuring product quality.

A4422—Analyze Product Throughput
Calculate the quantity of a product completed, check it against the schedule, and make it available to authorized personnel to view.

A4423—Provide Product Genealogy
Create record on the product for traceability, including operations, process parameters, lot number, batch number, supplier, operator identifications, product measurements, and any exceptional processing conditions occurred. Make the record available to authorized personnel.

A4424—Analyze Machine/Personnel Performance
Using the collected process data, analyze machine usage, production rate, capability, and estimate maintenance schedule. Also, analyze worker's performance, such as productivity, labor skill, and attendance record.

A vocabulary that facilitates reading the activity model is documented in the Appendix. Vocabulary includes two subsections: Terminology and ICOM (Input, Control, Output, and Mechanism) Data Definitions. Common terms referred in activity and ICOM data definitions are defined in the terminology subsection. All the data elements in ICOM are defined in the subsection of ICOM definitions.

Foundation Interfaces

The interfaces are specified using CORBA IDL and documented in a NIST report.[13] Some of them are derived from the activities of process planning, manufacturing execution, and their subactivities. Interface entities are developed. Attributes within each entity are based on the ICOM in the IDEF0 diagram in the previous section. Methods within each entity are based on the activities or subactivites in the IDEF0 diagram. For example, the Equipment Tracking interface corresponds to activity A431 Track Resources, and the interface Operation Sequencing corresponds to activity A411 Develop Production Activities. Equipment Tracking consists of one attribute of Equipment and two function calls, track_equipment and report_status, and this interface is used to define objects that are used for tracking a piece of machinery or a tool used in processing a workpiece in a factory and reporting the status of the equipment. The interface entities are organized into two modules: the manufacturing process planning module and the manufacturing execution module. Each module contains data structures, interfaces, and type definitions.

A scenario of using these interfaces can be described as follows. Based on the CORBA specifications, the use of these interfaces is to develop clients in the user's end and servers in the service provider's end. Clients are customers that use MES modules, such as job planning, job tracking, machine status, and tool usage. Typically in a factory, clients are those who need to develop production plans, dispatch tasks, develop resource plans, and so on, as well as those who need to acquire information on job status, resource status, and abnormality reports. For example, these people are typically production engineers, factory managers, product and process engineers, and business managers. On the server side, those service modules that are located on computer servers are implemented by the interfaces and can be called by clients. Connection between a client and a server that is requested by the client is based on CORBA interconnection protocols and technology.

5. Concluding Remarks

A set of foundation interfaces using CORBA/IDL for process planning and manufacturing execution software modules has been identified through object modeling. The interfaces will enable software modules in various hardware/software platforms and in different locations to exchange data and messages with each other. The object model in IDL will be updated to reflect emerging technologies and industrial practices in the future.

There is a major advantage in using CORBA—an open specification. The interfaces specified in this paper can not only be implemented in CORBA Interface Definition Language (IDL) but can also be directly implemented in web-friendly languages, such as JAVA and XML; however, there are some potential problems in using CORBA. Because the CORBA technology is still evolving, some basic communication protocols defined in CORBA have not been rigorous enough; therefore, they are subject to implementers' interpretations. This will cause failure in interoperability among clients and servers. Clients and servers that are created by different developers may not be able to communicate with each other.

For future work, these interfaces will be taken to standard bodies, such as OMG, as an input from NIST through the NIST participation. Also, the interfaces developed here can be used for testing commercial implementations in a MES testbed being established at NIST.

Acknowledgment

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Disclaimer

No approval or endorsement of any commercial products by the National Institute of Standards and Technology is intended or implied. Certain commercial software systems and interface specifications are identified in this report to facilitate understanding. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the software systems and interface specifications identified are necessarily the best available for the purpose.

Appendix

Terminology

The following terms are used in activity and ICOM definitions.

Batch:
One or more lots are identified as one group that is treated by some processes as a unit. After the batch is treated, the batch can be dissolved and individual lots are routed separately.

Job:
A batch or lot that is scheduled to be released for production. (A more detailed description is given in Ref. 10.)

Lot/Load:
One or more parts/components in a group that travel through the production process as a unit. Lot and load are synonymous. A lot has a release date and time, a due date/time, and an actual finished date/time.

Production Unit:
In a manufacturing facility (factory or shop), a product unit can be a batch, lot, or single part. Each production unit has a unique identification, maintained by the system.

Resources:
Skills and physical entities that are required for performing production activities. Examples are stock materials, equipment (machining centers, automatically guided vehicle, robots, measuring machines, and so on), tools (fixtures, cutters, adapters, hand tools, gages, computer programs, tapes, and more), labor skills, and energy.

Input, Control, Output, and Mechanism (ICOM) Data (information flow) Definitions

Actual Production Steps:
An actual production step is a detailed instruction to equipment or workers to execute production activity, such as load tools to a machine, start a milling cycle, drill a hole, check the actual dimension of a feature, and so on.

CAD/CAPP/CAM/PDM:
The computer systems for product design and modeling (CAD), engineering, process planning (CAPP), machining numerical control programming (CAM), product data/process management (PDM). A system includes interface, data repository, and data process software.[14]

Controller:
Usually hybrid hardware/software systems. Examples are distributed control systems (DCS), programmable logic controllers (PLC), distributed numerical control (DNC), and supervisory control and data acquisition (SCADA) systems.

Cost Report:
A report on the manufacturing costs of producing a part. It contains the costs of material, labor, usage of equipment, and so on.

Data Analyzer:
A software component that provides up-to-the-minute report of actual manufacturing operations results along with the comparison to past history and business expectations. The results include such measurements as resource utilization, resource availability, product cycle time, conformance to schedule, and performance to standards.

Data Collection Methods:
The use of data collectors to obtain information on workpieces, timing, personnel, lots, and other critical entities for production management in a timely manner.

Data Collector:
A collection of devices with control software that are linked to factory-flow production equipment to gather data either manually or automatically from the manufacturing facility in an up-to-the-minute timeframe.

Delivery Schedule:
The schedule of delivery of purchased resources.

Design Knowledge:
The information (rules, logic, or examples) that a human designer brings to bear on design problems, including design techniques and implementation techniques. Many different types of design knowledge are used in different design activities, such as decomposition knowledge, assignment knowledge, consolidation knowledge, and optimization knowledge.

Detailed Schedule:
A plan that specifies starting time and finished time of each production unit in the queue locally to an area in the manufacturing facility, such as a workcell, a workstation, or a machine.

Document Controller:
A mechanism, usually software, that controls records and forms that support product life cycle activities, such as manuals, drawings, computer models, procedures, recipes, programs, engineering change orders (ECO), shift-to-shift communication records, and so on.

ERP/MRPII:
Enterprise Resource Planning (ERP) and Manufacturing Resource Planning (MRP) II are the systems that provide financial, order management, productions and materials planning, and related functions. The modern systems focus on global planning, business processes, and execution across the whole enterprise (intra-enterprise systems), with an accrued recent importance of aspects like supply chain planning and the whole supply chain management aspects and extending to include the whole inter-enterprise supply chain.

Equipment Operation Instructions:
Specific operation steps or recipes that are used to control machine movement, such as machining, welding, assembly, material movement, and so on.

Labor Records:
A labor record is a piece of data that records the time, attendance, tasks performed, tasks assigned, skill level, and certificates of a worker.

List of Purchased Resources:
A list of resources that are purchased from suppliers. For each resource item, the list contains resource number, description, purchased date, quantity, cost, and other related information that is company specific.

Machine Tools:
A machine tool is a machine with accessories that provides the capability of machining, such as milling, turning, drilling, and grinding.

Manufacturing Bill of Material (BOM):
A list of parts that are scheduled to be manufactured in the factory. For each part, the BOM contains part number, description, quantity, description, and so on. Manufacturing BOM is the manufacturing version of product structure and part list in a corresponding production system, known as "as-built configuration," which support manufacturing engineers to consider additional information when planning how to manufacture the product, such as manufacturing capabilities, physical assembly possibilities, and the availability of parts.[15]

Manufacturing Execution System (MES):
A production activity management system that initiates, guides, responds to, and reports on production activities on-line and in real time to production management people. The system aids the Execute Manufacturing Orders activity.

Manufacturing Knowledge:
The information (rules, logic, examples) that a manufacturing engineer brings to bear on manufacturing engineering problems, including production techniques and implementation techniques. Many different types of manufacturing knowledge are used in different manufacturing activities, such as decomposition knowledge, assignment knowledge, consolidation knowledge, and optimization knowledge, which are used in process planning, resource planning, production planning, and scheduling.

Manufacturing Orders:
Instructions that are sent to factories to start jobs to fulfill customer orders. The starting dates are specified in the manufacturing order according to the production plan and the master production schedule.

Market/Customer Requirements:
A list of customer needs based on market studies, detailed evaluation of the competition, and review of all available literature. It includes the description on product performance, appearance, delivery time, target price, volume, safety, and environment.[16]

Master Production Schedule:
A plan that specifies starting time and finishing time of each job in the job queue that are for producing products required by customers. The plan contains job IDs, starting dates, and due dates.

Operation Sequence:
A set of step-by-step instructions that specify how to perform tasks to process a workpiece in a local area, such as a machine, a workstation, a workcell.

Personnel Assignments:
A list of workers who are assigned to perform specific operations in the production plan. Each worker is assigned to perform or monitor one or more operations, usually, with due dates.

Personnel Data:
A record of personnel assigned to perform production activities. It provides work hours, on-station time, skills, certificates, and so on.

Personnel Reassignments:
Requests to reassign workers to new tasks.

Personnel Tracking Component:
A software component in a MES that aids users to track workers in a manufacturing facility.

Planning Policies:
Rules, regulations, strategies to plan business, engineering, and production activities.

Process Adjustments:
Requests from operators to process planners to modify the process plan or to adjust certain predefined parameters to improve process performance.

Process Change Request:
Feedback from factory-floor production requesting changes to process plan when some problems in the process plan were found. Changes can be process parameter changes, tool changes, setup changes, and so on.

Process Management Component:
A software component in a MES that aids users to manage processes.

Process Performance:
Measures of how good parts, components, and products are produced by a process. Process performance include production rate, product quality, and process capability.

Process Plan:
A plan that specifies operation sequences, equipment, and process parameters for manufacturing a product.

Process Status:
A report of the conditions of a process being monitored. The report includes alarms, process changes or shifts, workpiece throughput, and so on.

Product Bill of Material (BOM):
An index to illustrate the structure and detailed information of product, component and part, known as "as-designed configuration" or "Engineering BOM-EBOM." It includes the item number of letter, the part number, the quantity needed in the assembly, the name or description of the component, the material from which the component is made, and the source of the component.[16,17]

Product Delivery:
Move finished products to customers who requested the products.

Product/Process Statistics:
Measurements and statistical analyses of process performance and quantities and the quality of products.

Product Genealogy Component:
One of the components in a MES that provides the visibility to where work is at all times and its disposition. Product genealogy information may include who worked on the product, components materials by supplier, lot, serial number, current production conditions, and any alarms, rework, or other exceptions related to the product. This information provides traceability of each part and component.

Product Inventory:
The inventory information on a product. The information is updated when finished products are sent to storage.

Product Order:
Quantities of parts or products to be produced, usually with nominal delivery dates, as specified by enterprise sources external to the manufacturing facility.

Product Status:
Current conditions of a product, including the quantity of the product made, check it against the schedule, measurement and test results, and any exceptional process conditions occurred.

Product Tracking Component:
A software component in a MES that aids users to track resources used in a manufacturing facility.

Production Activity Planning Component:
A software component in a MES that aids users to plan production activities.

Production Orders:
Instructions that are sent to a local area of a factory to start processing a production unit with the starting date and time and the ending date and time.

Production Statistics:
Measurements and statistical analyses of the production process and the quantity and quality of products being produced.

Production Status:
A report on the state of all scheduled operations and production units. This also includes the information on resources, process setup, job schedule, and material routing.

Production Unit Definition:
Definition of a lot or a batch. It includes an ID, number of workpieces, and the descriptions of the workpieces. Each workpiece may have a serial number. In the product record, workpiece ID and production unit ID are associated.

Production Unit Routing:
A plan that specifies the traveling route of a production unit in a manufacturing facility. The plan also specifies stops for processing and queuing.

Production Unit Scheduling Component:
A software component in a MES that aids users to schedule production unit to be processed locally in a manufacturing facility.

Production Unit Status:
A snapshot of a product unit being processed. The status includes the quantity of finished product, scrap rate, rework rate, product measurements analyses, and a check of the status with the master production schedule.

Purchase Orders:
A purchase order is an instruction to buy certain resources (material, parts, components, tools, machines, and so on) from a supplier.

Quality Statistics:
The statistical data pertinent to the quality of the product measured in-process or post-process based on the design specifications.[14]

Released Units:
Production units that are released for processing in the manufacturing facility.

Resource Availability:
A report on whether needed resources are available for production during specified time periods.

Resource Data:
The data that indicate the condition of a resource based on inspection or measurement analysis.

Resource Records:
A resource record is a piece of information that indicates where the resource is located and who is using it for which operations on which production unit for how long. If it is a piece of equipment, the record should also show whether it is functional.

Resource Release Orders:
A resource release order is an instruction that requests to release resources from storage or from current user to a new user.

Resource Requirements:
A list of resources required to support production jobs.

Resource Schedule:
A plan of control resource availability and allocation. It specifies a group of resources that each resource is assigned to which operation or transferred from one place to another in a specific time period. Only resources that are used/shared by multiple workcells or workstations are on the resource schedule.

Resource Scheduling Component:
A software component in a MES that aids users to schedule the release of resources to workcells, workstations, and/or machines.

Resource Statistics:
The statistical data pertinent to the state of

resources inspected or measured in-process or post-process.

Resource Status:
A snapshot of a resource used in production. The conditions, location, and service time of the resource are reported. If it needs maintenance, replacement, or disposition, the resource is marked accordingly.

Resource Tracking Component:
A software component in a MES that aids users to track resources being used in a manufacturing facility.

Service Delivery:
The delivery of post-sale service to customers.

Specifications:
Sets of description of standard engineering, manufacturing, and business practices that guide and control the product development process.

Statistical Quality Control (SQC):
A software component in a MES that aids users to analyze and control product quality and to monitor process capability and shift.

Sale and Service Management (SSM):
A mechanism that supports sales force automation, product configurations, service quoting, product returns, and post-sale service.

Standard Part Library:
An information library or database that contains standard parts. A standard part is a member of a class of parts that has a generic function and is manufactured routinely without reference to its use in any particular product. Examples of standard parts are screws, bolts, rivets, jar tops, buttons, most beams, gears, springs, and washers.

Supply Chain Management (SCM):
A mechanism that aids users to manage the supply of resources, including forecasting, distribution and logistics, transportation management, electronic commerce, and advanced planning.

Task Assignments:
Records of assigning tasks with due dates to workers.

Tool, Equipment Maintenance Order:
An instruction indicating specific tools, machines, or devices that need maintenance before performing any production activities.

Tool and Equipment Status:
The condition of all tools and equipment. Condition includes the usage load, wear and tear, broken status, and the forecasted life span.

Tool Usage Instructions:
Instructions that guide users to properly use tools in production.

Tooling Design:
Specification of the form, function, and material of a tool (for example, cutter, fixture, and probe). There are two major subtypes of tooling design: (1) tool assembly design that specifies the assembly of a tool or fixture from standard components, and (2) special tool design that must be fabricated.

Updated Document:
Document that is modified to include new information.

Workpiece Measurements:
The assessment and comparison of workpiece geometry, dimension, tolerance, and functions for the conformance to the design attributes.

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