MODAPTO [101091996]: Modular Manufacturing and Distributed Control via Interoperable Digital Twins

13.4.1 BPMN notation elements and workflow modeling principles

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Introduction

BPMN notation elements and workflow modeling principles provide the foundational knowledge for creating effective process models that support MODAPTO design reconfiguration capabilities. Understanding these elements and principles is essential for developing manufacturing process models that can be effectively executed, optimized, and reconfigured to meet changing production requirements.

Event elements represent occurrences that trigger, interrupt, or conclude process flows within manufacturing operations. Start events initiate process execution and can be triggered by various conditions such as production orders, material availability, or schedule requirements. Start events represent how a process begins, such as receiving an email, and after the user receives the email, the rest of the BPMN diagram may proceed.

Intermediate events occur during process execution and can represent conditions such as equipment status changes, quality checkpoints, or material transfers between production stages. End events signify process completion and can indicate different outcomes such as successful completion, error conditions, or cancellation scenarios.

Activity elements define the work performed within manufacturing processes and represent the core operational content of production workflows. Task activities represent atomic operations that cannot be further decomposed, such as individual machining operations, assembly steps, or inspection procedures. Manual task types are used whenever an activity must be executed manually without outside help or application, such as loading a truck with product.

Sub-process activities represent compound operations that contain their own internal workflow structures, enabling hierarchical modeling of complex manufacturing processes.

Different task types address specific operational scenarios common in manufacturing environments. Service tasks represent automated operations performed by manufacturing equipment or software systems. Service tasks are any tasks that use an automated application or web service to complete the task.

User tasks require human intervention and represent operations performed by manufacturing personnel. Script tasks execute automated logic or calculations that support process decision-making. Send and receive tasks handle communication between different process participants or systems.

Gateway elements control process flow and implement decision logic that determines how manufacturing processes proceed under different conditions. Exclusive gateways implement decision points where process flow continues down exactly one path based on specified conditions. These patterns handle complex business process logic across multiple endpoints, such as executing process flows in parallel, message correlation, and escalating processes.

Parallel gateways create multiple concurrent process paths that enable simultaneous operations on different production resources. Inclusive gateways activate one or more paths based on multiple condition evaluations, supporting complex decision scenarios common in manufacturing operations.

Sequence flow elements define the order and timing of activities within manufacturing processes. Standard sequence flows represent normal process progression from one activity to the next. Conditional sequence flows implement branching logic based on process variables, equipment status, or quality measurements. Default sequence flows provide fallback paths when conditional flows are not activated. Message flows represent communication between different process participants or systems that may be operating independently.

Data elements represent information that flows through manufacturing processes and influences process behavior. Data objects represent information created, modified, or consumed by process activities, such as production orders, quality records, or configuration parameters. Data objects can represent data placed into the process, data resulting from the process, data that needs to be collected, or data that needs to be stored, with tasks often being data-dependent, meaning they cannot proceed until certain data has been collected.

Data stores represent persistent information repositories such as databases or file systems that maintain information across multiple process instances.

Pool and lane elements organize process models to represent different participants, organizational units, or systems involved in manufacturing operations. Pools represent major participants such as different manufacturing departments, supplier organizations, or customer entities. Lanes subdivide pools to represent specific roles, equipment types, or functional areas within larger organizational units. This organizational structure clarifies responsibilities and communication patterns within complex manufacturing processes.

Workflow modeling principles guide the creation of effective process models that accurately represent manufacturing operations while supporting analysis, optimization, and execution requirements. The principle of semantic clarity ensures that process models accurately represent the intended manufacturing operations without ambiguity or misinterpretation. This requires careful selection of BPMN elements that precisely match the operational semantics of manufacturing activities.

The principle of appropriate abstraction balances model detail with usability, ensuring that models contain sufficient information to support their intended purposes without unnecessary complexity that impedes understanding or maintenance. Manufacturing process models must capture essential operational characteristics while remaining manageable for analysis and modification during reconfiguration activities.

The principle of modular design encourages the creation of process models that can be composed from reusable components, supporting efficient model development and maintenance. Modular design enables creation of standard process fragments that can be combined to create complete manufacturing workflows, reducing development time and ensuring consistency across similar operations.

The principle of executable compatibility ensures that process models can be translated into operational control instructions for manufacturing systems. This requires careful consideration of how BPMN elements map to actual manufacturing control systems and adherence to modeling patterns that support reliable automated execution.

The principle of stakeholder alignment ensures that process models serve the needs of different stakeholders including process designers, manufacturing engineers, operators, and management personnel. BPMN 2.0 provides a common graphical language for end-to-end business process workflows that can be readily adopted and easily understood.

This requires balancing technical accuracy with visual clarity and providing appropriate views for different stakeholder needs.

Validation principles ensure that BPMN models are structurally correct, semantically consistent, and operationally feasible. Structural validation checks verify that models comply with BPMN syntax rules and metamodel constraints. Semantic validation ensures that models accurately represent intended manufacturing operations. Operational validation confirms that models can be effectively executed within available manufacturing resources and constraints.

References

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