Initial Manufacturing Exchange Specification (IMES): Requirements Analysis for the Plant Layout Application

Y. Tina Lee

U.S. DEPARTMENT OF COMMERCE
Technology Administration
Manufacturing Systems Integration Division
National Institute of Standards and Technology
Manufacturing Engineering Laboratory
Gaithersburg, MD 20899-0001
Initial Manufacturing Exchange Specification (IMES): Requirements Analysis for the Plant Layout Application

Y. Tina Lee

U.S. DEPARTMENT OF COMMERCE
Technology Administration
Manufacturing Systems Integration Division
National Institute of Standards and Technology
Manufacturing Engineering Laboratory
Gaithersburg, MD 20899-0001

July 1998
Initial Manufacturing Exchange Specification (IMES):
Requirements Analysis for the Plant Layout Application

Y. Tina Lee
Manufacturing Systems Integration Division
Manufacturing Engineering Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899-0001

Preface

The High Performance Computing and Communication (HPCC) program\(^1\) was formally established by the High Performance Computing Act of 1991 (Public Law 102-194). The goal of this program is to accelerate the development of future generations of high performance computers and networks and the use of these resources in the government and throughout the U.S. economy. National Institute of Standards and Technology's Systems Integration of Manufacturing Applications (SIMA) Program\(^2\) coordinates many of the agency's HPCC activities associated with manufacturing. SIMA is addressing the information interface needs of the U.S. manufacturing community. Specifically, the SIMA program works with U.S. industry to:

* Develop information exchange and interface protocols to address manufacturing integration problems,
* Establish test mechanisms for validating protocols and implementations, and
* Transfer information technology solutions to manufacturing enterprises.

The primary output of the SIMA Program will be a collection of specifications called Initial Manufacturing Exchange Specifications (IMES)\(^3\). IMES provides the means to improve the SIMA Program's ability to meet the needs of the U.S. industry in the area of standards and testing methods by providing a structured approach to the SIMA Program's activities in this arena. They will fill an important void in the manufacturing systems integration process as it exists today. Each IMES will be developed through an industry review and consensus process. It is expected that the manufacturing community will accept them as an authoritative

---

Three types of IMES have been identified: an interface specification between a human being and a software application; an interface specification between two or more software applications; and a reference information repository specification. Each IMES involves several components that define the integration aspect, specifies a definitive solution to the integration problem, and demonstrates the validity of the proposed solution. It must contain a clear description of WHAT information the interface or repository MUST convey, and possibly HOW it is conveyed. The content is usually specified by an information model of all the objects and related information attributes which are covered by the specification.

To support the scope and domain specifications, the IMES shall address a particular "example scenario," identifying an actual interface/information requirement derived from a real industrial problem. The proof of the value of the IMES to industry will be the ability to build a prototype to the IMES, using the software applications actually used by the industrial practitioners, and solving the cited problem. To support the development of an IMES, SIMA projects will have seven phases: identify/define the industry need, conduct requirements analysis, develop proposed solution, validate proposed solution, build consensus, transfer technology, and initiate standardization. Each of these phases has a well-defined set of deliverables.

This document follows the Phase I IMES document of the Production Systems Engineering component of the Production and Product Data Management Project within SIMA\textsuperscript{1}. The Phase I IMES document identified and documented the industry need, technical specifications to be developed, potential collaborators, a proposed technical approach, and a manufacturing scenario for the project; it also describes the relationships between the proposed project, the SIMA Reference Architecture, other related projects, and current standards activities.

This document describes the results of the requirements analysis phase (the IMES Phase II) for a neutral interface specification to plant layout design and simulation software. The interface specification should provide a neutral mechanism capable of describing exchange data between plant layout design and simulation systems for manufacturing systems. The interface specification is independent of any particular commercial software system. This document defines the context, scope, and information requirements for conveying manufacturing layout information between design and simulation software applications according to the guidelines established for National Institute of Standards and Technology (NIST) IMES.

The outline of this document includes: scope, standards review, definitions and abbreviations, information requirements, and an annotated bibliography. Section 1 defines the scope of the IMES and presents an application activity model that is the basis for the definition of the scope. Section 2 lists normative references that constitute provisions of this IMES. Section 3 provides definitions and abbreviations of terms that are used in the discourse of the IMES. Section 4 specifies the information required for the exchange of plant layout information between design and simulation software. The annotated bibliography section identifies key references with a

\textsuperscript{1} McLean, C. and Leong, S., "Industrial Need: Production System Engineering Integration Standards," NISTIR 6019, National Institute of Standards and Technology, Gaithersburg, MD, May 1997.
short paragraph summary of each reference.

This Phase II IMES requirements analysis document is a strawman for a neutral interface specification to plant layout design and simulation software. The document will continue to evolve based on experience and feedback from others involved in this effort. NIST plans to hold informal review meetings with interested participants from the manufacturing industry and academia to review IMES documents. This IMES document will serve as the basis for these informal review meetings.

Work described in this paper was sponsored by the NIST Systems Integration of Manufacturing Applications (SIMA) program. Certain commercial software and hardware products are identified in this paper. This does not imply approval or endorsement by NIST, nor does it imply that the identified products are necessarily the best available for the purpose.
1 SCOPE
This Initial Manufacturing Exchange Specification (IMES) specifies the use of the integrated resources necessary for the exchange of information for manufacturing plant layout. It defines an interface for conveying manufacturing plant layout information between design and simulation software applications. The information includes the basic data required for material flow analysis and activity analysis of the manufacturing plant, the significant features of the site on which the plant is located, the external shape and characteristics of the plant's components or items, and the layout design. This IMES aims at designing or simulating a plant layout for discrete parts manufacturing with an initial focus on the engineering of small assembly lines for electromechanical products production.

A significant portion of the data requirements of this IMES is also the data requirements for the ISO 10303-227, Application Protocol: Plant Spatial Configuration, or AP227. The AP 227 specifies the information required for process plants with a central emphasis on piping systems. The information includes the shape and spatial arrangement characteristics of piping system components as well as the shape and spatial arrangement characteristics of other related plant systems that impact the design and layout of piping systems. The common requirements of this IMES and the AP 227 include the shape, location, functional characteristics, and physical arrangement of a plant and plant components. The AP 227, therefore, serves as the frame for developing the IMES. The followings are within the scope of this IMES, but outside the scope of the AP 227: characteristics of product, production activities relationships, materials flow and material handling methods, and activity/equipment space requirements.

Areas that are outside the scope of this IMES include process planning and scheduling, site selection, equipment selection, internal design of equipment, commercial aspects of procurement procedures, corporate guidelines, regulations and standards, plant's installation instructions and scheduling, cost estimation, and safety evaluation.

1.1 Application Activity Model (AAM)
The application activity model (AAM) is provided to aid the understanding of the scope and information requirements defined in this IMES. The model is presented as a set of definitions of the activities and the data, and a set of activity figures. It covers activities that go beyond the subject of this IMES. The definitions given in this section do not supersede the definitions given in the normative text. The diagrams use IDEF0 notation: activities/functions are represented by "boxes," data/objects such as inputs, controls, outputs, and mechanisms (ICOM) are represented by "arrows," and boxes and arrows are labeled. If an activity has been decomposed, a separate figure is included.

As with any IDEF0 model, the application activity model is dependent on a particular viewpoint

and purpose. The viewpoint of the AAM is the users of plant spatial configuration information, including architect, engineer, and builder. The purpose of the AAM is to clarify the context and scope of this IMES. Activities and data flows which are out of scope of this IMES are marked with asterisks.

1.1.1 AAM definitions and abbreviations
The following terms are used in the application activity model. Terms marked with an asterisk are outside the scope of this IMES.

1.1.1.1 Analyze basic data (Activity A1)

The activity of gathering and analyzing data required by the facilities designer. Data may include information regarding product design, assembly operations, and existing plant conditions. Data analysis will be the activities including flow analysis of materials, equipment, and personnel, and activity analysis of production activities.

1.1.1.2 Approve layout (Activity A33)

The activity of analyzing the proposed layout design. This may result in an approval of the design or recommendations for changes in the design.

1.1.1.3 Change request (ICOM)

A request made by the designers, management, and other interested parties for changes to the original plant design due to errors, omissions, and/or other reasons. A request is followed by review, analysis, and approval.

1.1.1.4 Corporate guideline* (ICOM)

Procedures, instructions, or specifications that are developed based on best practice, standards, or recommendations. It is used in the development of plant layout.

1.1.1.5 Design Conceptual plant layout (Activity A2)

The activity of producing a preliminary plant layout design.

1.1.1.6 Design strategy (ICOM)

Strategy for producing the plant layout design. It encompasses the state of art technology, regulation and standards, and costs.
1.1.1.7 Determine material handle method (Activity A12)

The activity of performing the analysis of the material required and the quantities necessary along with a review of the material handling personnel to determine the proper method of material handling. Factors to be taken into account when handling material include the type of equipment available, the inventory requirements, and the existing processing schedule.

1.1.1.8 Determine plant layout method (Activity A21)

The activity of selecting the method to constructing or representing the layout design. Basic layout methods include sketches, 2-D templates, 3-D scale models, and combination of 2-D templates and 3-D models.

1.1.1.9 Determine prod. equip. requirements (Activity A13)

The activity of analyzing the manufacturing resources and process specifications to identify the production equipment which will be used to make up the resulting facility. The identified production equipment, existing or new, may include processing equipment and inspection equipment.

1.1.1.10 Determine space requirements (Activity A14)

The activity of determining the amount of space needed to manufacture the product. Factors to be taken into account when considering space requirements include equipment, material, personnel, and activities.

1.1.1.11 Develop master plan for layout (Activity A22)

The activity of designing a preliminary plant spatial arrangement based on things such as the space requirements, equipment requirements, and material handling plan.

1.1.1.12 Develop plant layout (Activity A0)

The activity of developing an optimal layout for the equipment to maximize performance and/or quality for the production facility.

1.1.1.13 Equipment (ICOM)

A generic term used to describe any mechanism that facilitates the performance of a function,
excluding personnel, systems, and facilities.

1.1.1.14 Equipment list (ICOM)

The list of equipment used for production and for material handling.

1.1.1.15 Equipment requirements (ICOM)

Specifications for kind and quantity of machines and equipment needed to support the product's life-cycle.

1.1.1.16 Establish final plant layout (Activity A3)

The activity of designing the final plant layout, an optimal layout based on the given requirements and resources.

1.1.1.17 Evaluate layout (Activity A31)

The activity of evaluating the preliminary layout design for resulting in an optimal layout. This may result in recommendation of the necessary alternations/change to the preliminary design.

1.1.1.18 Facilities (ICOM)

The buildings and grounds in which the product is produced. Facility aspects include things such as the actual square footage of the building, plant layout, loading docks, and ventilation.

1.1.1.19 Finalize layout (Activity A32)

The activity of producing the final layout which is ready to be installed or implemented.

1.1.1.20 Identify plant performance requirements (Activity A11)

The activity of ascertaining the plant operating characteristics and activities necessary to achieve the plant production objectives and plant owner's operational goals such as plant availability, plant safety, and methods of production.
1.1.1.21 Layout authorizations* (ICOM)

Management authorization, imperatives, directives, and procedures for initiating and executing project activities.

1.1.1.22 Manufacturing resources (ICOM)

Identification of the resources available to the plant for a given product. Resources include work-cells, machines, and personnel.

1.1.1.23 Material destination (ICOM)

Plan for moving of materials in the production of the product. It lists which material will be needed at a particular location.

1.1.1.24 Material handling equipment (ICOM)

The list of material handling equipment used for moving materials from one location to another, for example, from workstation to workstation or from inventory to workstation.

1.1.1.25 Material handling plan (ICOM)

Identification of material destination, material arrival time (optional), material handling method, and material handling equipment selection.

1.1.1.26 Owner's plant requirements* (ICOM)

An initial statement of plant requirements provided by the plant owner. It may include specifications, standards, and design requirements.

1.1.1.27 Personnel (ICOM)

Individuals trained and employed by the organization.

1.1.1.28 Plant configuration (ICOM)

Identification of characteristics of the plant. This may include plant's type, construction, size, shape, and restrictions.
1.1.1.29 Plant performance requirements (ICOM)

Description of the quantity and quality of a product to be produced by the plant.

1.1.1.30 Plant physical data* (ICOM)

Physical data of the plant, new or existing. Data may include plant's geological data, building dimensions/drawing, floor and ceiling load limits, and existing layout.

1.1.1.31 Preliminary layout design (ICOM)

Specification of the master layout developed and evaluated by facility designers and other interested parties. The layout will be submitted for examination and approval.

1.1.1.32 Process specifications (ICOM)

Description of the high-level engineering specifications for the manufacture of the product. This may include material selections, process selections, and equipment and skills selections.

1.1.1.33 Product specifications (ICOM)

Descriptions of functional specifications, performance specifications, appearance specifications, and other engineering specifications for the product.

1.1.1.34 Production requirements (ICOM)

Requirements for meeting estimated production demand for products produced in the plant. This may be stated in terms of product range and volume, equipment capabilities and capacities, and workforce levels.

1.1.1.35 Regulation and standards* (ICOM)

Specifications or instructions, that impact various activities related to the plant, issued by government or industry.

1.1.1.36 Safety evaluation reports* (ICOM)

The results of the analysis of the plant design with respect to the safety issues.
1.1.1.37  Space requirements (ICOM)

Specifications of the amount of space needed for production activities requiring significant amounts of space.

1.1.1.38  System layout design (ICOM)

Definitions or representation of the floor-plan for the manufacturing facility. It may include information of identifying and locating processing equipment, material handling equipment, machine controllers, storage spaces and systems, transport systems and routings, and walkways.

1.1.1.39  Systems (ICOM)

Any methodology or network that is logically designed to facilitate the achievement of an objective through analysis and the sharing of information.

1.1.1.40  Time/cost estimation* (ICOM)

Projected or forecasted cost and length of time to design, produce, or procure a plant item, to obtain a service, or to layout the plant.

1.1.2  AAM Diagrams

The application activity model is given in the following five diagrams. The graphical form of the application activity model is presented in the IDEF0 activity modeling format.
Data flows that are out of scope are marked with asterisks.
Design Conceptual plant layout
The following standards contain provisions which, through reference in this text, constitute provisions of IMES. All standards are subject to revision, and parties to agreements based on this IMES are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.


DEFINITIONS AND ABBREVIATIONS

This section provides definitions and abbreviations of terms that are used throughout this IMES. Section 3.1 lists terms defined in other documents and standards, while section 3.2 provides definitions of terms. Section 3.3 spells out acronyms and abbreviations that are used in this IMES.

3.1 Terms Defined in Other Documents or Standards

This subsection specifies terms that have been defined in other publications. Section 3.1.1 lists terms defined in ISO 10303-1; Section 3.1.2 lists terms defined in ISO 10303-227; and section 3.1.3 lists terms defined in International Federation for Information Processing (IFIP) document.

3.1.1 Terms defined in ISO 10303-1

This IMES makes use of the following terms defined in ISO 10303-1:

- application;
- application activity model (AAM);
- conformance class;
- implementation method;
- integrated resource;
- product;
- product data;
- unit of functionality (UoF).

3.1.2 Terms defined in ISO/CD 10303-227

This IMES makes use of the following terms defined in ISO 10303-227:

- actual;
- basic engineering data;
- branch;
- catalogue;
- component;
- functional;
- functional characteristics;
- functional requirements;
- instrument;
- plant;
- plant item;
- plant system;
- site;
- spatial arrangement.

3.1.3 Terms defined in the IFIP Glossary of Terms Used in Production Control
This IMES makes use of the following terms defined in the International Federation for Information Processing (IFIP) Classified Glossary:

3.1.3.1 Terms Related to Product Design
- product design;
  - product;
- product specification;
- parts list;
  - part;
  - component;
  - assembly;
  - sub-assembly;
  - balanced product set;
  - bill of materials;
- material specification;
  - direct material;
  - indirect material;
  - bulk material;
  - general material;
  - special material;
  - material type;
  - material form;
  - blank;
- drawing;
  - dimension;
  - acceptance limits;
  - unilaterial limits;
  - bilateral limits;
  - tolerance;
- quality control.
3.1.3.2 Terms Related to Production Planning

- production planning;
  - factory planning;
  - process planning;
  - operation planning;

- work center;
  - machine tool;
  - processing plant;
  - equipment;
  - service plant;
  - plant list;
  - plant layout;

- productive work;
  - element;
  - operation;
  - process;
  - processing stage;
  - process charts;
  - flow chart;

- method;
  - route card;
  - operation sheet;
  - route sheet;

- material flow system;
  - flow network;
  - flow path;

- production flow analysis;
  - company flow analysis;
  - factory flow analysis;
  - group analysis;
  - line analysis;
  - tooling analysis;

- process control;

- tooling;
  - tooling family;
  - consumable tools;

- work study;

- method study;

- work measurement;
  - operation time;
  - set-up time;
  - down time;
  - idle time;
  - process time;
  - loading time.
3.2 Other Definitions
For the purposes of this IMES, the following definitions apply:

- activity analysis: the process of analyzing the interrelationships among production activities. The analysis is primarily concerned with the non-quantitative factors that influence the location of activities.

- assembling process: the joining of two or more parts or assemblies by using mechanical force or bonding.

- casting and molding process: the process that involves pouring molten metal into a mold patterned after the part to be manufactured, allowing it to cool, and removing the metal from the mold.

- conditioning process: the process that uses heat, chemical action, or mechanical means to change mechanical properties, such as hardness, ductility, or elasticity of the material.

- finishing process: the process that uses electroplating, vacuum metallizing, anodizing, painting, galvanizing, or polishing technique to beautify and/or protect the surface of a material.

- flow analysis: the activity of analyzing the flow of materials, people and equipment with the flow of material as the primary concern. The analysis concentrates on some quantitative measures of movement between activities.

- forming process: the process that uses a shaping device and pressure to cause material to take on a new size and shape.

- material handling: the activity of moving, storing, and controlling material.

- plant layout: the design of an arrangement of the physical elements of a plant.

- separating process: the process that removes excess material to produce the desired size, shape, feature, and surface finish.

3.3 Abbreviations
For the purposes of this IMES, the following abbreviations apply:

AAM Application Activity Model
AE Architectural/Engineering
AEC Architecture, Engineering, and Construction
B-rep Boundary representation
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSG</td>
<td>Constructive Solid Geometry</td>
</tr>
<tr>
<td>HPCC</td>
<td>High Performance Computing and Communication program</td>
</tr>
<tr>
<td>HVAC</td>
<td>Heating, Ventilation, and Air Conditioning</td>
</tr>
<tr>
<td>ICAM</td>
<td>The U.S. Air Force’s Integrated Computer Aided Manufacturing Program</td>
</tr>
<tr>
<td>ICOM</td>
<td>Data /Objects of Inputs, Controls, Outputs, or Mechanisms to the IDEF0 Activity</td>
</tr>
<tr>
<td>IDEF</td>
<td>ICAM Definition Method</td>
</tr>
<tr>
<td>ID</td>
<td>Identifier</td>
</tr>
<tr>
<td>IFIP</td>
<td>International Federation for Information Processing</td>
</tr>
<tr>
<td>IMES</td>
<td>Initial Manufacturing Exchange Specifications</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>NIST</td>
<td>National Institute of Standards and Technology</td>
</tr>
<tr>
<td>PDM</td>
<td>Product Data Management</td>
</tr>
<tr>
<td>SIMA</td>
<td>NIST’s System Integration of Manufacturing Applications Program</td>
</tr>
<tr>
<td>STEP</td>
<td>Standard for the Exchange of Product Model Data</td>
</tr>
<tr>
<td>UoF</td>
<td>Unit of Functionality</td>
</tr>
</tbody>
</table>
4 INFORMATION REQUIREMENTS
This section specifies the information required for the exchange of manufacturing layout between design and simulation application systems.

The information requirements are specified as a set of units of functionality, application objects, and application assertions. These assertions pertain to individual application objects and to relationships between application objects. The information requirements are defined using terminology of the subject area of this IMES.

4.1 Units of Functionality
This subsection specifies the UoFs for the manufacturing plant layout. This IMES specifies the following UoFs:

- activity_closeness_relationship UoF;
- change_information UoF;
- materials_flow UoF;
- plant_characterization UoF;
- plant_item_characterization UoF;
- plant_item_shape UoF;
- plant_shape UoF;
- product_information UoF;
- production_activities UoF;
- site_characterization UoF.

The units of functionality and a description of the functions that each UoF supports are given below. The application objects included in the UoFs are defined in 4.2.

4.1.1 activity_closeness_relationships UoF
The activity_closeness_relationship UoF identifies the space closeness relationship between activity areas that include material storage rooms, primary operations areas, or shipping and handling areas.

The following objects are used by the activity_closeness_relationship UoF:

- Activity_space_required;
- Area_closeness_relationship;
- Equipment_space_required;
- Necessary_flow_between_work_areas.

4.1.2 change_information UoF
The change_information UoF describes information such as the design change requests and approvals for modifications to Plant objects, Plant_item objects, Plant_system objects, and other components associated with the Plant.

The following objects are used by the change_information UoF:

- Change;
- Change_approval;
- Change_delta;
- Change_item;
- Change_life_cycle_stage;
- Change_life_cycle_stage_sequence;
- Change_life_cycle_stage_usage;
- Changed_planned_physical_plant;
- Changed_plant;
- Changed_plant_item;
- Changed_plant_item_location;
- Changed_plant_item_shape;
- Changed_plant_process_capability;
- Changed_plant_system;
- Changed_reference_geometry;
- Changed_required_material_description;
- Changed_site;
- Changed_site_feature;
- Changed_sited_plant;
- Changed_sub_plant_relationship.

4.1.3 materials_flow UoF
The materials_flow UoF describes information that is needed to perform materials flow analysis for the Plant to operate to produce the product.

The following objects are used by the materials_flow UoF:

- Material_handling_equipment;
- Material_handling_cost;
- MaterialSpecification_selection;
- Part_routing_and_intensity;
- Required_material_description.

4.1.4 plant_characterization UoF
The plant_characterization UoF describes identifiable collections of Plant_item objects that perform specific functions within a Plant. The Plant_item objects are functionally dependent on one another for the performance of the system. The collection of Plant_system objects as a whole enable the Plant to operate.

The following objects are used by the plant_characterization UoF:

- Electrical_system;
- External_classification;
- Functional_plant;
- Functional_plant_satisfaction;
- Hvac_system;
- Location_in_plant;
- Planned_physical_plant;
4.1.5 **plant_item_characterization** UoF
The *plant_item_characterization* UoF describes major elements of which *Plant* objects and *Plant_system* objects are comprised. These are items within a *Plant* that occupy space and possess physical, measurable characteristics. This UoF specifies spatial and/or physical information about *Equipment* and components of other *Plant_system* objects. This UoF describes specification and catalogue information of certain *Plant_item* objects. It also describes the spatial shape and position of volumes of space in a *Plant*.

The following objects are used by the *plant_item_characterization* UoF:

- Catalogue_definition;
- Catalogue_item;
- Catalogue_item_substitute;
- Design_project;
- Electrical_component;
- Equipment;
- Functional_design_view;
- Functional_plant_item_satisfaction;
- Hvac_component;
- Installed_physical_design_view;
- Physical_design_view;
- Planned_physical_plant_item;
- Plant_item;
- Plant_item_definition;
- Plant_item_design_view;
- Plant_item_instance;
- Plant_item_location;
- Plant_volume;
- Project_design_assignment;
- Relative_item_location;
- Reserved_space;
- Route;
- Spare_plant_item_usage;
- Supplied_equipment;
- Supplier;
- System_space.

4.1.6 plant_item_shape UoF
The plant_item_shape UoF specifies the representation of Plant_item shapes using constructive solid geometry (CSG) primitives or wireframe models and boundary representation (B-rep) geometry. CSG primitives are bounded by simple geometric surfaces such as planes, cylinders, cones, toruses, and spheres. CSG primitives may be combined using boolean operations.

The following objects are used by the plant_item_shape UoF:

- B_rep_element;
- Block;
- Circular_ellipsoid;
- Cone;
- Conic;
- Csg_element;
- Curve;
- Cylinder;
- Extrusion;
- Free_form_curve;
- Line;
- Point;
- Polygon;
- Pyramid;
- Solid_of_revolution;
- Sphere;
- Surface;
- Torus;
- Trimmed_block;
- Trimmed_cone;
- Trimmed_cylinder;
- Trimmed_pyramid;
- Trimmed_sphere;
- Trimmed_torus.
- Tube;
- Vector;
- Wire_and_surface_element.

4.1.7 plant_shape UoF

The plant_shape UoF specifies the external shapes of components, assemblies of components, and volumes of a Plant. The component's external shape can be specified as an envelope of the space occupied by a component, as an outline of the component, or as a detailed definition of the component's shape.
The following objects are used by the *plant_shape* UoF:

- Detail_shape;
- Envelope_shape;
- Gis_position;
- Interfering_shape_element;
- Outline_shape;
- Plant_item_centreline;
- Plant_item_interference;
- Plant_item_interference_status;
- Plant_item_shape;
- Reference_geometry;
- Shape_interference_zone_usage;
- Shape_parameter;
- Shape_representation;
- Shape_representation_element;
- Shape_representation_element_usage;
- Site_shape_representation.

**4.1.8 product_information UoF**

The *product_information* UoF describes the type, the description, and the quantity of the product that the plant will produce.

The following objects are used by the *product_information* UoF:

- Manufacturing_line;
- Parts_in_product;
- Plant_process_capability;
4.1.9  production_activities UoF
The production_activities UoF describes all activities that are needed for the Plant to operate to produce the product.

The following objects are used by the production_activities UoF:

- Activity_of_the_part;
- Number_of_subassemblies;
- Operations_on_part;
- Sequence_of_operations.

4.1.10  site_characterization UoF
The site_characterization UoF describes the significant features of the Site on which the Plant is located. It includes information about the site location, infrastructure like roads and sewers, buildings and other structures located on the Site, and the shape of the terrain on which a Building or Site_feature is located.

The following objects are used by the site_characterization UoF:

- Breakline;
- Building;
- Facet_trigon;
- Faceted_surface_representation;
- Location_in_building;
- Location_in_site;
- Point_and_line_representation;
- Site;
- Site_feature;
- Sited_plant;
- Survey_point.

4.2 Application Objects
This subsection specifies the application objects for this IMES. Each application object is an atomic element that embodies a unique application concept and contains attributes specifying the data elements of the object. (Note: Identifiers that are given to attributes are presented in lowercase, while identifiers of application objects are presented with the first character capitalized.) The application objects and their definitions are listed below.

4.2.1 Activity_of_the_part
The Activity_of_the_part specifies the operations description and timing requirements at the activity area where the part is produced.

The data associated with Activity_of_the_part is the following:

- activity_area;
- part_name;
- activity_description;
- lot_size;
- preparation_time.
- part_produce_time.

4.2.1.1 activity_area
The activity_area is the area where specific operations are performed.

4.2.1.2 part_name
The part_name is the name of the part that is produced at the activity area.

4.2.1.3 activity_description
The activity_description specifies the activity area's process.
4.2.1.4  lot_size

The *lot_size* is the number of parts produced per run.

4.2.1.5  preparation_time

The *preparation_time* is the amount of time required to get ready to run the part.

4.2.1.6  part_produce_time

The *part_produce_time* is the amount of time required to make one part. It does not include the preparation time.

4.2.2  Activity_space_required

The *Activity_space_required* specifies the estimated space dimensions required for the activity to be performed.

The data associated with *Activity_space_required* is the following:

- activity_area;
- activity_type;
- equipment_used;
- space.

4.2.2.1  activity_area

The *activity_area* is the area where specific operations are performed.

4.2.2.2  activity_area_type

The *activity_area_type* specifies the space classifications. The space classifications most often used are: primary operations (forming, molding, etc.), secondary operations (light assembly), inspection and testing, storage, service and support, shipping and handling, offices, and main aisles.

4.2.2.3  equipment_used

The *equipment_used* lists the equipment and pieces of equipment required, if any, for the activity area.
4.2.2.4 space

The *space* is the space requirements (in square feet, in general) of the activity area.

4.2.3 Area_closeness_relationship

The *Area_closeness_relationship* specifies the closeness desired between two activity areas.

The data associated with *Activity_space_required* is the following:

- activity_area_1;
- activity_area_2;
- relationship.

4.2.3.1 activity_area_1

The *activity_area_1* is the first activity area that the area closeness relationship will be established with the second activity area.

4.2.3.2 activity_area_2

The *activity_area_2* is the second activity area that the area closeness relationship will be established with the first activity area.

4.2.3.3 relationship

The *relationship* specifies the closeness desired relationship between activity_area_1 and activity_area_2. The *relationship* may be classified as: abnormally high, especially high, important, ordinary, and unimportant.

4.2.4 B_rep_element

A *B_rep_element* is a type of *Shape_representation_element* that is composed of geometric and topological elements.

4.2.5 Block

A *Block* is a type of *Csg_element* that is a 3D right rectangular solid. A *Block* may be a *Trimmed_block*.
4.2.6 Breakline

A Breakline is a contiguous set of straight line segments that designate a path across a Site_shape_representation.

4.2.7 Building

A Building is a partially or totally enclosed structure located on a Site that contains Plant_system objects or provides supporting infrastructure within its boundaries.

The data associated with Building is the following:

- building_id;
- location_and_orientation;
- name;
- shape.

4.2.7.1 building_id

The building_id specifies a unique number used to identify the building.

4.2.7.2 location_and_orientation

The location_and_orientation specifies the position of the Building relative to the site coordinate system and the orientation of the Building relative to a specified direction.

4.2.7.3 name

The name specifies a textual label given to the Building.

4.2.7.4 shape

The shape specifies the outline or characteristic surface configuration or contour of the building.

4.2.8 Catalogue_definition

A Catalogue_definition is the identification of a document that lists Catalogue_item objects.

The data associated with Catalogue_definition is the following:

- catalogue_id;
- catalogue_name;
- catalogue_version.

4.2.8.1 catalogue_id

The catalogue_id specifies a unique identifier given to a catalogue.

4.2.8.2 catalogue_name

The catalogue_name specifies a textual label given to the catalogue.

4.2.8.3 catalogue_version

The catalogue_version specifies a particular release of a catalogue within a sequence of catalogue releases.

4.2.9 Catalogue_item

A Catalogue_item is an item whose characteristics are standardized and have been categorized in a library or catalogue.

The data associated with Catalogue_item is the following:

- item_name;
- item_version;
- model_number.

4.2.9.1 item_name

The item_name specifies a textual label that is used by the supplier to refer to the Catalogue_item.

4.2.9.2 item_version

The item_version specifies a particular release of a Catalogue_item within a sequence of Catalogue_item releases.

4.2.9.3 model_number

The model_number is the identifier assigned by the supplier to one or more Catalogue_item objects.
4.2.10  Catalogue_item_substitute

A Catalogue_item_substitute is an alternate Catalogue_item that can be used instead of the specified Catalogue_item.

4.2.11  Change

A Change is the modification or requested modification of a Plant_item.

The data associated with Change is the following:

- business_unit;
- change_id;
- change_reason;
- change_summary;
- date;
- project_number;
- revision;
- title.

4.2.11.1  business_unit

The business_unit specifies the organization(s), company(s), or functional group(s) responsible for the Change.

4.2.11.2  change_id

The change_id specifies a unique identifier for the Change.

4.2.11.3  change_reason

The change_reason specifies the rationale for the Change.

4.2.11.4  change_summary

The change_summary specifies a general description of the Change.
4.2.11.5 date

The date specifies the calendar day-month-year and time that the Change was initiated on.

4.2.11.6 project_number

The project_number specifies a designation assigned to identify projects within an organization. More than one project (and therefore more than one project_number) may be associated with a Change.

4.2.11.7 revision

The revision specifies the particular amendment of the Change within a sequence of amendments.

4.2.11.8 title

The title specifies a descriptive label for the Change.

4.2.12 Change_approval

A Change_approval is the endorsement by an authority of the change in status of a specific Change.

The data associated with Change_approval is the following:

- approval_date;
- approver;
- approver_role.

4.2.12.1 approval_date

The approval_date specifies the specific calendar day-month-year and time when the approval authority signed the Change as approved.

4.2.12.2 approver

The approver specifies the name of the individual who endorsed the Change.

4.2.12.3 approver_role

The approver_role specifies the purpose or function of the approver that approves a change.
4.2.13 Change_delta

A Change_delta is the relationship between a previous Change_item and the current Change_item.

4.2.14 Change_item

A Change_item is an item that may be modified, for which there is a request to modify, or is the result of a modification to a Change_item. Each Change_item may be one of the followings: a Changed_planned_physical_plant, a Changed_plant, a Changed_plant_item, a Changed_plant_item_location, a Changed_plant_item_shape, a Changed_plant_process_capability, a Changed_plant_system, a Changed_reference_geometry, a Changed_required_material_description, a Changed_sited_plant, a Changed_site, a Changed_site_feature, or a Changed_sub_plant_relationship.

The data associated with Change_item is the following:

- change_item_id;
- creation_date;
- description;
- item_owner;
- status.

4.2.14.1 change_item_id

The change_item_id specifies a unique identifier for a Change_item.

4.2.14.2 creation_date

The creation_date specifies the calendar day-month-year and time on which the Change_item is created.

4.2.14.3 description

The description specifies a textual explanation or summary of the item being changed.

4.2.14.4 item_owner

The item_owner specifies the name of the person or organization that owns the item being changed and is responsible for implementing or approving the change.
4.2.14.5 status

The status specifies the textual description of the existence condition of a Change_item.

4.2.15 Change_life_cycle_stage

A Change_life_cycle_stage is a state in the life-cycle of the Change that indicates or classifies the status or disposition of the Change.

The data associated with Change_life_cycle_stage is the following:

- name.

The name specifies a textual label given to the stage.

4.2.16 Change_life_cycle_stage_sequence

A Change_life_cycle_stage_sequence is the mechanism that specifies the sequence of life-cycle stages.

4.2.17 Change_life_cycle_stage_usage

A Change_life_cycle_stage_usage is the assignment of a Change to a particular Change_life_cycle_stage.

The data associated with Change_life_cycle_stage_usage is the following:

- date_of_activation;

- date_of_completion;

- description.

4.2.17.1 date_of_activation

The date_of_activation specifies the calendar day-month-year and time when the Change was assigned to the Change_life_cycle_stage. A specific ordering of the day, month, and year within the date is not required.

4.2.17.2 date_of_completion

The date_of_activation specifies the calendar day-month-year and time when the Change was released from, or completed, the assigned life-cycle stage.
4.2.17.3 description

The description specifies a textual explanation or summary of the assignment of the Change to a particular stage.

4.2.18 Changed_planned_physical_plant

A Changed_planned_physical_plant is a type of Change_item that identifies a Planned_physical_plant that is being changed or is the result of a Change.

4.2.19 Changed_plant

A Changed_plant is a type of Change_item that identifies a Plant that is being changed or is the result of a Change.

4.2.20 Changed_plant_item

A Changed_plant_item is a type of Change_item that identifies a Plant_item that is being changed or is the result of a Change.

4.2.21 Changed_plant_item_location

A Changed_plant_item_location is a type of Change_item that identifies a Plant_item_location that is being changed or is the result of a Change.

4.2.22 Changed_plant_item_shape

A Changed_plant_item_shape is a type of Change_item that identifies a Plant_item_shape that is being changed or is the result of a Change.

4.2.23 Changed_plant_process_capability

A Changed_plant_process_capability is a type of Change_item that identifies a Plant_process_capability that is being changed or is the result of a Change.

4.2.24 Changed_plant_system

A Changed_plant_system is a type of Change_item that identifies a Plant_system that is being changed or is the result of a Change.
4.2.25 Changed_reference_geometry

A Changed_reference_geometry is a type of Change_item that identifies a Reference_geometry that is being changed or is the result of a Change.

4.2.26 Changed_required_material_description

A Changed_required_material_description is a type of Change_item that identifies a Required_material_description that is being changed or is the result of a Change.

4.2.27 Changed_site

A Changed_site is a type of Change_item that identifies a Site that is being changed or is the result of a Change.

4.2.28 Changed_site_feature

A Changed_site_feature is a type of Change_item that identifies a Site_feature that is being changed or is the result of a Change.

4.2.29 Changed_sited_plant

A Changed_sited_plant is a type of Change_item that identifies a Sited_plant that is being changed or is the result of a Change.

4.2.30 Changed_sub_plant_relationship

A Changed_sub_plant_relationship is a type of Change_item that identifies a Sub_plant_relationship that is being changed or is the result of a Change.

4.2.31 Circular_ellipsoid

A Circular_ellipsoid is a type of Csg_element that has the following geometric characteristics: it is axially symmetric; cross sections taken in a plane normal to the axis are circular; cross sections taken in a plane containing the axis are elliptical; it is trimmed with a plane that is normal to an axis. The shape of a Circular_ellipsoid may be described as a hemisphere that has been compressed along the circular axis.

4.2.32 Cone

A Cone is a type of Csg_element that is a 3D volume with parallel, coaxial, circular cross
sections of radii that varies uniformly from a circular base to an axis normal to and positioned at the center point of the base. A Cone may also be a Trimmed_cone (see 4.2.123).

4.2.33 Conic

A Conic is a type of Curve composed of points located at a uniform distance from a point, a pair of points, or a point and a line.

4.2.34 Csg_element

A Csg_element is a type of Shape_representation_element that is a regular, 3D geometric shape that is combined with other regular shapes through boolean operations to create a complex, 3D, solid model. Each Csg_element may be one of the followings: a Block, a Circular_ellipsoid, a Cone, a Cylinder, an Extrusion, a Pyramid, a Solid_of_revolution, a Sphere, or a Torus.

4.2.35 Curve

A Curve is a type of Wire_and_surface_element that is a one-dimensional manifold in a space of dimension two or three. A Curve is either a Conic, a Free_form_curve, a Line, a Polygon, or a Vector.

4.2.36 Cylinder

A Cylinder is a type of Csg_element that is a 3D cylindrical solid primitive with end surfaces that are planar and are perpendicular to the axis. The size and shape of a Cylinder is completely described by two real values that represent the radius and length of the cylinder. A Cylinder may be a Trimmed_cylinder. A Cylinder may also be a Tube (see 4.2.128).

4.2.37 Design_project

A Design_project is a task with a specifically defined purpose and scope that is used for the administration and management of plant designs.

The data associated with Design_project is the following:

- description;
- design_project_id;
- name;
- owner.
4.2.37.1  description

The *description* specifies a textual explanation or summary of the *Design_project*.

4.2.37.2  design_project_id

The *design_project_id* specifies a unique identifier for the *Design_project*.

4.2.37.3  name

The *name* specifies a textual label given to the *Design_project*.

4.2.37.4  owner

The *owner* specifies the name of the organization that is responsible for the *Design_project*.

4.2.38  Detail_shape

A *Detail_shape* is a type of *Plant_item_shape* that is the actual or intended external shape of a *Plant_item*. A *Detail_shape* does not include the description of voids or other internal details of the shape of the *Plant_item*.

NOTE - Contrast *Detail_shape* with *Outline_shape* and *Envelope_shape*. A *Detail_shape* more closely approximates the actual shape of the *plant_item* than either *Envelope_shape* or *Outline_shape* and is, therefore, likely to be more complex than either *Envelope_shape* or *Outline_shape*.

4.2.39  Electrical_component

An *Electrical_component* is a type of *Plant_item* that is an individually identifiable and functional part of an *Electrical_system*.

4.2.40  Electrical_system

An *Electrical_system* is a type of *Plant_system* that is a system of wiring, switches, relays, and other equipment associated with receiving and distributing electrical power.

The data associated with *Electrical_system* is the following:

- system_voltage_designation;
- type.
4.2.40.1 system_voltage_designation

The *system_voltage_designation* is the rated voltage of the system.

4.2.40.2 type

The *type* specifies a designation that classifies the *Electrical_system* based on the kind of service that it provides.

4.2.41 Envelope_shape

An *Envelope_shape* is a type of *Plant_item_shape* that is a 3D spatial volume that completely encloses or bounds a Plant_item. An *Envelope_shape* is a very simple geometric shape, such as a box, that encloses the plant item. An *Envelope_shape* may, but need not, include clearance or access spaces associated with the plant item.

 NOTE - Contrast *Envelope_shape* with *Detail_shape* and *Outline_shape*.

4.2.42 Equipment

An *Equipment* is a type of *Plant_item* that is treated as a single and self-contained unit that provides a function. Each *equipment* may be used to perform one of the following processes: materials handling, casting and molding, forming, separating, conditioning, assembling, and finishing.

The data associated with Equipment is the following:

- equipment_characteristics;

- equipment_type;

- equipment_general_description.

4.2.42.1 equipment_characteristics

The *equipment_characteristics* specifies functional attributes of the *Equipment*.

4.2.42.2 equipment_type

The *equipment_type* specifies a classification of *Equipment* based on its performance characteristics.
4.2.42.3 equipment_general_description

The equipment_general_description specifies the equipment's manufacturer, model number, and serial number.

4.2.43 Equipment_space_required

The Equipment_space_required specifies the estimated working space required for a piece of required equipment or related group of equipment.

The data associated with Equipment_space_required is the following:

- equipment_name;
- space_for_equipment;
- space_for_operator;
- space_for_material_be_worked_on;
- space_for_moving_equipment.

4.2.43.1 equipment_name

The equipment_name specifies a designation or label assigned to the equipment.

4.2.43.2 space_for_equipment

The space_for_equipment specifies the estimated space required for the equipment.

4.2.43.3 space_for_operator

The space_for_operator specifies the estimated space required for the operator to work on the equipment.

4.2.43.4 space_for_material_be_worked_on

The space_for_material_be_worked_on specifies the estimated space required for handling material that is used by the equipment.

4.2.43.5 space_for_moving_equipment

The space_for_moving_equipment specifies the estimated space required for repairing or moving the equipment.
4.2.44  **External_classification**

An *External_classification* is a designation and description that classifies a *Plant_item*, *Plant*, or *Plant_system* based on predefined tables or sources defined externally to this part. The designation is a reference to the predefined table or source.

The data associated with *External_classification* is the following:

- description;
- name;
- source.

4.2.44.1  **description**

The *description* specifies a textual explanation or summary of the *External_classification*.

4.2.44.2  **name**

The *name* specifies a textual label given to the *External_classification*.

4.2.44.3  **source**

The *source* specifies a designation that identifies a table or document that contains a list of candidate classifications that the name and description are drawn from.

4.2.45  **Extrusion**

An *Extrusion* is a type of *Csg_element* that is a closed, 2D profile swept through a linear distance in space.

4.2.46  **Facet_trigon**

A *Facet_trigon* is a planar, polygonal surface with three sides.

4.2.47  **Faceted_surface_representation**

A *Faceted_surface_representation* is a type of *Site_shape_representation* that consists of a collection of *Facet_trigon* objects that represent the topography of a *Site*. 
4.2.48 Free_form_curve

A Free_form_curve is a type of Curve. It is a one-dimensional, contiguous set of points.

4.2.49 Functional_design_view

A Functional_design_view is a type of Plant_item_design_view that indicates that data associated with the Plant_item are the logical characteristics of a Plant_item rather than the physical.

The data associated with Functional_design_view is the following:

- tag_number.

The tag_number specifies an optional identifier assigned to the Plant_item for purposes of functional identification and eventual physical tracking.

4.2.50 Functional_plant

A Functional_plant is a Plant that describes the functional characteristics of the Plant.

4.2.51 Functional_plant_satisfaction

A Functional_plant_satisfaction is the assignment of an actual Planned_physical_plant to a Functional_plant for the purpose of satisfying the functional requirements with a physical object.

4.2.52 Functional_plant_item_satisfaction

A Functional_plant_item_satisfaction is the assignment of a Physical_design_view to a Functional_design_view for the purpose of satisfying the functional requirements with a physical object.

4.2.53 Gis_position

A Gis_position is the positioning and orientation information necessary for transforming coordinate values between a local coordinate space and the global coordinate system of earth. Transformation procedures depend upon the geographic information system (GIS) coordinate system. Each Gis_position object designates the global position and orientation of a Site_shape_representation.

The data associated with a Gis_position is the following:
- height;
- scale;
- system;
- x_axis_delta_x;
- x_axis_delta_y;
- x_coordinate;
- y_coordinate;
- zone.

4.2.53.1 height

The height specifies the distance above sea level or reference level in the GIS coordinate system.

4.2.53.2 scale

The scale specifies a transformation factor applied to the conversion of point coordinates between a local coordinate system and a GIS coordinate system. The precise application of the transformation will depend on the GIS system.

4.2.53.3 system

The system specifies the identifier of the GIS system being used.

4.2.53.4 x_axis_delta_x

The x_axis_delta_x specifies the abscissa value of the end point of a vector indicating the positive x axis of the GIS coordinate space in the local coordinate system.

4.2.53.5 x_axis_delta_y

The x_axis_delta_y specifies the coordinate value of the end point of a vector indicating the orientation or the positive x axis of GIS coordinate space in the local coordinate system.

4.2.53.6 x_coordinate

The x_coordinate specifies the distance from the y axis of the coordinate space defined by the GIS system and zone.
4.2.53.7  y-coordinate

The y-coordinate specifies the distance from the x axis of the coordinate space defined by the GIS system and zone.

4.2.53.8  zone

The zone specifies a subdivision of the earth's surface based on the GIS system.

4.2.54  Hvac_component

An Hvac_component is a type of Plant_item that is an individually identifiable item or combination of items that is part of an HVAC system.

4.2.55  Hvac_system

An Hvac_system is a type of Plant_system that controls the temperature, humidity, cleanliness, and circulation of environmental air as required in a Building.

4.2.56  Installed_physical_design_view

An Installed_physical_design_view is an indication that the Plant_item described by a Physical_design_view is physically installed within the Plant.

The data associated with Installed_physical_design_view is the following:

- serial_number.

The serial_number specifies a designation that uniquely identifies a particular physical Plant_item that is installed in a Plant.

4.2.57  Interfering_shape_element

An Interfering_shape_element is the portion of the Plant_item_shape that is interfered with by a shape element of another.

The data associated with Interfering_shape_element is the following:

- interference_colour.

The interference_colour specifies the color that displays the element.
4.2.58 Line

A Line is a type of Curve that is a one-dimensional, contiguous set of points that are positioned at a constant distance from a vector or that constitute the shortest distance between two points.

4.2.59 Location_in_building

A Location_in_building is a type of Plant_item_location that is the position of the Plant_item relative to the Building.

4.2.60 Location_in_plant

A Location_in_plant is a type of Plant_item_location that is the position of the Plant_item relative to the Plant.

4.2.61 Location_in_site

A Location_in_site is a type of Plant_item_location that is the position of the Plant_item relative to the Site.

4.2.62 Manufacturing_line

A Manufacturing_line is a type of Plant that is defined by the type of product(s) it produces.

4.2.63 Material_handling_equipment

The Material_handling_equipment is the device that performs the material handling activity.

The data associated with Material_handling_equipment is the following:

- equipment_name;
- equipment_type;
- equipment_speed;
- available_equipment_quantity;
- unit_load_value.
4.2.63.1  equipment_name

The *equipment_name* is the name of the material handling system.

4.2.63.2  equipment_type

The *equipment_type* specifies the type of equipment used for material handling. As example, the types of material handling equipment include hand-carry, hand truck, manual pallet truck, powered pallet truck, tractor trailer, lift truck, straddle carrier, automatically guided vehicle, crane, or conveyor.

4.2.63.3  equipment_speed

The *equipment_speed* is the average speed of the material handling equipment. The average speed is estimated to allow for starting, turning, and stopping of the material handling equipment.

4.2.63.4  available_equipment_quantity

The *available_equipment_quantity* is the number of the material handling equipment that will be available.

4.2.63.5  unit_load_value

The *unit_load_value* is the maximum number of parts that will be moved by the material handling equipment at a time.

4.2.64  Material_handling_cost

The *Material_handling_cost* estimates the total cost of the material handling equipment used per time unit. The cost includes labor cost, power cost, and maintenance cost.

4.2.65  Material_specification_selection

A *Material_specification_selection* is the candidate material specifications for a system design.

The data associated with *Material_specification_selection* is the following:

- description;
- material_specification_id;
- required_or Optional;
- selection_id;
- type.

4.2.65.1 description

The description specifies a textual summary of the selected material specification.

4.2.65.2 material_specification_id

The material_specification_id specifies a unique identifier for the material specification selected.

4.2.65.3 required_or_optional

The required_or_optional specifies whether the material specification is required or whether its use is optional.

4.2.65.4 selection_id

The selection_id specifies a unique identifier for the candidate material specification.

4.2.65.5 type

The type specifies a designation that classifies a Material_specification_selection based on selection criteria.

4.2.66 Necessary_flow_between_work_areas

The Necessary_flow_between_work_areas specifies the required flow of work from one work place to the next.

4.2.67 Number_of_subassemblies

The Number_of_subassemblies specifies the number and the type of subassemblies required to finish the final product. A subassembly is the result of preliminary (partial) assembly, whereby a number of parts are formed into a unit.

4.2.68 Operations_on_part

The Operations_on_part specifies the number and the type of operations on each part or at each activity center.
4.2.69 Outline_shape

An Outline_shape is a type of Plant_item_shape that is a 3D spatial volume that corresponds to the bounding surface features of a Plant_item.

NOTE - Contrast with Detail_shape and Envelope_shape. An Outline_shape is a simple geometric representation of plant item; this representation may be called a cartoon. The representation is a more accurate representation of the shape of the Plant_item than that provided by an Envelope_shape, but not nearly as precise as a Detail_shape.

4.2.70 Parts_in_product

The Parts_in_product lists all part types within the product and quantity of each product’s part required to assemble one finished product.

4.2.71 Part_routing_and_intensity

The Part_routing_and_intensity specifies the part flow from one activity to another and the flow related data.

The data associated with Part_routing_and_intensity is the following:

- part_name;
- part_move_from;
- part_move_to;
- distanceMoved;
- selected_material_handling_equipment;
- routing_type;
- flow_intensity.

4.2.71.1 part_name

The part_name is the name of the part.

4.2.71.2 part_move_from

The part_move_from specifies the activity area from which the part moves.
4.2.71.3 part_move_to

The part_move_to specifies the activity area to which the part moves.

4.2.71.4 distance_moved

The distance_moved specifies the estimated distance the average part will move from one step to the next.

4.2.71.5 selected_material_handling_equipment

The selected_material_handling_equipment specifies the name of the material handling equipment that is used to move the part.

4.2.71.6 routing_type

The routing_type specifies the routing classification for accounting or documenting purpose.

4.2.71.7 flow_intensity

The flow_intensity uses the conventional designations for recording the intensity of material flow. The intensity designations are: abnormally high, especially high, important, ordinary, and unimportant.

4.2.72 Physical_design_view

A Physical_design_view is a type of Plant_item_design_view that describes the physical and spatial characteristics of a Plant_item.

4.2.73 Planned_physical_plant

A Planned_physical_plant is the set of physical and spatial characteristics that a Plant can have, including siting, location, and orientation.

4.2.74 Planned_physical_plant_item

A Planned_physical_plant_item is a type of Plant_item_instance that is intended to have physical existence in the real world and that has been used or instanced in a design.

    The data associated with Planned_physical_plant_item is the following:

    - type.
The type specifies a designation that classifies the Plant_item.

4.2.75 Plant

A Plant is a portion of an installation (or the entire installation) required to operate to produce products.

The data associated with Plant is the following:

- definition_coordinate_system;
- description;
- name;
- operators;
- owners;
- plant_id.

4.2.75.1 definition_coordinate_system

The definition_coordinate_system is the origin and axes of the Plant that serve as the basis for the location and orientation of Plant_items and sub-plants in the Plant.

4.2.75.2 description

The description specifies a textual explanation or summary of the Plant. The description need not be specified for a particular Plant. There may be more than one description for a Plant.

4.2.75.3 name

The name specifies a textual label given to the Plant.

4.2.75.4 operators

The operators specifies the name of the organization(s) responsible for the operation of the Plant. For a given plant, the operators need not be specified.

4.2.75.5 owners

The owners specifies the name of the organization(s) that owns the Plant. For a given plant, the owners need not be specified.
4.2.75.6 plant_id

The plant_id specifies a unique identifier for the Plant.

4.2.76 Plant_item

A Plant_item is an identifiable item that has a shape and that may be used as a component of the Plant. The Plant_item needs not be a physical item, but may be an allocation of space reserved for a purpose. Each Plant_item may be one of the following: a Plant_item_definition or a Plant_item_instance. Each Plant_item may be one of the following: an Electrical_component, an Equipment, or an Hvac_component.

The data associated with Plant_item is the following:

- description;
- name;
- plant_item_id.

4.2.76.1 description

The description specifies a textual explanation or summary of the Plant_item.

4.2.76.2 name

The name specifies a textual label given to the Plant_item.

4.2.76.3 plant_item_id

The plant_item_id specifies a unique identifier for the Plant_item.

4.2.77 Plant_item_centreline

A Plant_item_centreline is a type of Reference_geometry that is a center of symmetry of an aspect of the shape of the Plant_item.

4.2.78 Plant_item_definition

A Plant_item_definition is a type of Plant_item that has been designed to some level of completeness, but has not been used as the design for physical Plant_item objects.
4.2.79 Plant_item_design_view

A Plant_item_design_view is the collection of information about a Plant_item that is associated with a particular design phase. Each Plant_item_design_view may be one of the following: a Functional_design_view or a Physical_design_view.

4.2.80 Plant_item_instance

A Plant_item_instance is a planned type of Plant_item, as instanced in a spatial, functional or other design. Each Plant_item_instance is a Planned_physical_plant_item or a Plant_volume.

4.2.81 Plant_item_interference

A Plant_item_interference is where the spatial volume occupied by a Plant_item overlaps the space occupied by one or more Plant_item objects.

The data associated with Plant_item_interference is the following:

- interference_id;
- type.

4.2.81.1 interference_id

The interference_id specifies an identifier for the Plant_item_interference.

4.2.81.2 type

The type specifies the classification assigned to the Plant_item_interference based on the level of the clash.

4.2.82 Plant_item_interference_status

A Plant_item_interference_status is a designation indicating the state of resolution of an identified interference.

The data associated with Plant_item_interference_status is the following:

- assessor;
- status.
4.2.82.1 assessor

The assessor specifies the individual or organization assigned with the responsibility for resolving the Plant_item_interference.

4.2.82.2 status

The status specifies a designation indicating the state of resolution of an identified Plant_item_interference.

4.2.83 Plant_item_location

A Plant_item_location is the position of the Plant_item within a Plant. The position of a Plant_item is specified as the transformation (translation and rotation) of a point and axes on the Plant_item to a point and axes in the destination coordinate system. Each Plant_item_location is either a Location_in_building, a Location_in_plant, a Location_in_site, or a Relative_item_location.

The data associated with Plant_item_location is the following:

- location_and_orientation;

- location_id.

4.2.83.1 location_and_orientation

The location_and_orientation specifies the relative position and orientation of the Plant_item within the Plant.

4.2.83.2 location_id

The location_id specifies a unique identifier for the Plant_item_location.

4.2.84 Plant_item_shape

A Plant_item_shape is the volumetric representation of a Plant_item. Each Plant_item_shape may be one of the following: a Detail_shape, an Envelope_shape or an Outline_shape.

The data associated with Plant_item_shape is the following:

- clash_detection_class;

- origin;
- shape_id.

4.2.84.1 clash_detection_class

The `clash_detection_class` specifies a designation that classifies a `Plant_item_shape` for the purposes of interference checking. The value of the `clash_detection_class` attribute shall be one of the following:

- hard: the `Plant_item_shape` is used for clash detection and indicates that the shape cannot occupy the same physical space with another hard shape;

- ignore: the `Plant_item_shape` is not used for clash detection;

- soft: the `Plant_item_shape` is used for clash detection and indicates that the shape can occupy the same space with another soft shape and, depending on the circumstances, may occupy the same space as a hard object.

NOTE - A hard clash refers to an interference between two `Plant_item_shapes` whose `clash_detection_class` is "hard". A soft clash refers to an interference between two `Plant_item_shapes` where at least one of the `Plant_item_shapes` has a `clash_detection_class` of "soft". A no clash refers to an interference between two `Plant_item_shapes` where at least one of the `Plant_item_shapes` has a `clash_detection_class` of "ignore".

4.2.84.2 origin

The `origin` specifies the locating point for the geometric shape of a `Plant_item`.

4.2.84.3 shape_id

The `shape_id` specifies a unique identifier for the `Plant_item_shape`.

4.2.85 Plant_process_capability

A `Plant_process_capability` is a functional behavior that can be executed by the `Plant`.

The data associated with `Plant_process_capability` is the following:

- `plant_process_capability_id`;

- `production_capacity`.

4.2.85.1 plant_process_capability_id

The `plant_process_capability_id` uniquely identifies a particular `plant_process_capability`.
4.2.85.2 production_capacity

The *production_capacity* specifies the rated output of the *Plant* with respect to a *plant_process_capability*.

4.2.86 Plant_system

A *Plant_system* is a combination of *Plant_item* objects that perform a function required for the *Plant* to operate to produce products. Each *Plant_system* may be one of the following: an *Electrical_system*, a *Hvac_system*, or an *Equipment*.

The data associated with *Plant_system* is the following:

- name;
- *plant_system_id*;
- *service_description*.

4.2.86.1 name

The *name* specifies a textual label given to the *Plant_system*.

4.2.86.2 plant_system_id

The *plant_system_id* specifies a unique identifier for the *Plant_system*.

4.2.86.3 service_description

The *service_description* specifies a textual or summary label for the system.

4.2.87 Plant_system_assembly

A *Plant_system_assembly* is a collection of *Plant_system* objects into a higher-level system to perform a functional capability.

4.2.88 Plant_volume

A *Plant_volume* is a type of *Plant_item_instance* that is a specifically defined volume located within a *Plant* that may, but need not be occupied by physical *Plant_item* objects. Each *Plant_volume* may be one of the following: a *Reserved_space*, a *Route*, or a *System_space*.

The data associated with *Plant_volume* is the following:
The type specifies a designation that classifies the Plant_volume.

4.2.89  Point

A Point is a type of Wire_and_surface_element that is a dimensionless location in space.

4.2.90  Point_and_line_representation

A Point_and_line_representation is a type of Site_shape_representation represented as a collection of Point objects that define the surface grid of the topography of a Site.

4.2.91  Polygon

A Polygon is a type of Curve that is composed of a set of points connected by line segments that form a planar, closed, non-self-intersecting figure.

4.2.92  Product_specification

The Product_specification specifies a set of unique identifiers and a general description of the functional specifications, performance specifications, appearance specifications and/or other engineering specifications for the product. The identifiers, assigned by the designers, are used to identify product’s photographs, prototypes, drawings, part lists, bill of materials, or assembly charts.

4.2.93  Production_rate

The Production_rate is the product quantity per time unit.

4.2.94  Project_design_assignment

A Project_design_assignment is an assignment of a Plant_item to a Design_project. The set of Project_design_assignment instances for a project defines the items and areas that are part of the project.

4.2.95  Pyramid

A Pyramid is a type of Csg_element that is a 3D volume with a rectangular base and four triangular sides that meet at an apex. The axis of a pyramid is the line segment from the center of the base to the apex. A Pyramid may be a Trimmed_pyramid.
4.2.96 Reference_geometry

A Reference_geometry is the identification of one or more Shape_representation_element objects in a model that are not part of a component shape, but provide additional geometric information relative to the shape of the Plant_item. Each Reference_geometry may be a Plant_item_centreline.

The data associated with Reference_geometry is the following:

- name;
- reference_geometry_id.

4.2.96.1 name

The name specifies a textual label given to the Reference_geometry.

4.2.96.2 reference_geometry_id

The reference_geometry_id specifies a unique identifier assigned to the Reference_geometry.

4.2.97 Relative_item_location

A Relative_item_location is a type of Plant_item_location that is the relative position of the Plant_item with respect to another Plant_item.

4.2.98 Required_material_description

A Required_material_description is a specification of the substances or the requirements of the substances that a component is to be made from.

The data associated with Required_material_description is the following:

- description;
- material_requirement_id.

4.2.98.1 description

The description specifies a textual explanation or summary of the required materials.
4.2.98.2 material_requirement_id

The material_requirement_id specifies a unique identifier for the specification that identifies the required material.

4.2.99 Reserved_space

A Reserved_space is a type of Plant_volume that is a region of space that is not to be obstructed by physical objects for reasons related to plant operation. Reserved_space includes maintenance volume, operator access, and safety zone.

4.2.100 Route

A Route is a type of Plant_volume that is a 3D path from one location to another. A Route is a conceptual engineered path that reserves space for a Plant_system.

4.2.101 Sequence_of_operations

The Sequence_of_operations specifies the operations to be performed on each component of a product and the order of operations to be performed.

4.2.102 Shape_interference_zone_usage

A Shape_interference_zone_usage is the representational elements that define the shape of a volume that encloses the region of space where the interference of clashing Plant_items occurs.

4.2.103 Shape_parameter

A Shape_parameter is a name-value pair that specifies the dimensional value of some aspect of the Plant_item_shape.

The data associated with Shape_parameter is the following:

- name;

- value.

4.2.103.1 name

The name specifies a textual label given to a dimension or a parameter of a Plant_item_shape.
4.2.103.2 value

The value specifies a number that represents the measure of the dimension or parameter of the Plant_item_shape.

4.2.104 Shape_representation

A Shape_representation is a combination of geometric elements that describe or define the general or specific surface boundaries of a Plant_item.

4.2.105 Shape_representation_element

A Shape_representation_element is a geometric model that is used to represent the shape or some aspect of the shape of a Plant_item. Each Shape_representation_element is either a B_rep_element, a Csg_element, or a Wire_and_surface_element.

The data associated with Shape_representation_element is the following:

- element_id.

The element_id specifies the unique identifier of the Shape_representation_element.

4.2.106 Shape_representation_element_usage

A Shape_representation_element_usage is an assignment of a Shape_representation_element to a Shape_representation of a Plant_item. Shape_representation_element_usage is the mechanism that aggregates the geometric elements that represent the shape of the plant_item.

The data associated with Shape_representation_element_usage is the following:

- element_colour;

- layer.

4.2.106.1 element_colour

The element_colour specifies the color that displays the element.

4.2.106.2 layer

The layer specifies the collection of displayable items for the purpose of controlling visibility and presentation style.
4.2.107 Site

A Site is a geographical location where the Plant is located.

The data associated with Site is the following:

- address;
- coordinates;
- elevation;
- environmental_references;
- locality;
- name;
- orientation;
- owners;
- site_id.

4.2.107.1 address

The address specifies the street address (including city, state, and zip code as appropriate) of the Site.

4.2.107.2 coordinates

The coordinates specifies the longitude and latitude coordinates of the Site with respect to a known point on the Site.

4.2.107.3 elevation

The elevation specifies the distance that the Site is located above sea level with respect to a known point on the Site.

4.2.107.4 environmental_references

The environmental_references specifies a reference to a document that provides environmental information relevant to the Site.
4.2.107.5 locality

The locality specifies the municipality or region where the Site is located.

4.2.107.6 name

The name specifies a textual label given to the Site.

4.2.107.7 orientation

The orientation specifies the relative alignment of the Site with respect to a given compass direction.

4.2.107.8 owners

The owners specify the company or organization that is financially responsible for the Site.

4.2.107.9 site_id

The site_id specifies a unique identifier for the Site.

4.2.108 Site_feature

A Site_feature is the composition, proportion, form, or outward appearance of some thing of interest on a Site.

The data associated with Site_feature is the following:

- location_and_orientation;
- man_made_or_natural;
- shape;
- site_feature_id;
- type.

4.2.108.1 location_and_orientation

The location_and_orientation specifies the position of the Site_feature relative to the site coordinate system and the orientation of the Site_feature relative to a specified direction.
4.2.108.2 man_made_or_natural

The *man_made_or_natural* specifies that the *Site_feature* is either man-made or natural, and provides a short descriptive name or title of the feature.

4.2.108.3 shape

The *shape* specifies a 3D spatial volume that completely encloses or bounds a feature.

4.2.108.4 site_feature_id

The *site_feature_id* specifies a unique identifier for the *Site_feature*.

4.2.108.5 type

The *type* specifies a designation that classifies a *Site_feature* based on its physical and functional characteristics.

4.2.109 Site_shape_representation

A *Site_shape_representation* is a replica of the topography of a specific area. Each *Site_shape_representation* is either a *Faceted_surface_representation* or a *Point_and_line_representation*.

The data associated with *Site_shape_representation* is the following:

- site_shape_representation_id.

The *site_shape_representation_id* specifies a unique identifier for the *Site_shape_representation*.

4.2.110 Sited_plant

A *Sited_plant* is a *Planned_physical_plant* that a site location has been defined for.

The data associated with *Sited_plant* is the following:

- plant_site_location;

- plant_site_orientation.
4.2.110.1 plant_site_location

The plant_site_location specifies the geographic position of the plant relative to the Site or a feature of the Site.

4.2.110.2 plant_site_orientation

The plant_site_orientation specifies the directional orientation of the plant with respect to the Site.

4.2.111 Solid_of_revolution

A Solid_of_revolution is a type of Csg_element that is formed by sweeping a 2D shape about an axis. The 2D shape may be closed or open; if open, then the ends of the 2D shape must lie on the sweep axis.

4.2.112 Spare_plant_item_usage

A Spare_plant_item_usage is an association between a primary Plant_item and a Plant_item. It is used as a spare for the primary Plant_item.

4.2.113 Sphere

A Sphere is a type of Csg_element that is a solid bounded by a surface at a constant radius from a centre point. A Sphere may be a Trimmed_sphere.

4.2.114 Sub_plant_relationship

A Sub_plant_relationship is the relationship between Plant objects and sub-plants and defines their relative locations.

The data associated with Sub_plant_relationship is the following:

- location_and_orientation.

The location_and_orientation specifies the relative position and orientation of the sub-plant within the Plant.

4.2.115 Supplied_equipment

A Supplied_equipment is an Equipment that is, or is to be, provided by a Supplier for use in a Plant.
The data associated with Supplied_equipment is the following:

- delivery_date;
- purchase_order_number;
- requisition_number.

4.2.115.1 delivery_date

The delivery_date specifies the calendar day-month-year and time when the Equipment was, or is, scheduled to be delivered to the Site.

4.2.115.2 purchase_order_number

The purchase_order_number specifies an identifier assigned to the Equipment purchase order.

4.2.115.3 requisition_number

The requisition_number specifies an identifier assigned to a written request for a piece of Equipment.

4.2.116 Supplier

A Supplier is the organization that produces a piece of Equipment or publishes a catalogue.

The data associated with Supplier is the following:

- supplier_id;
- vendor_name.

4.2.116.1 supplier_id

The supplier_id specifies a unique identifier for the supplier.

4.2.116.2 vendor_name

The vendor_name specifies a textual label used by the company or organization that is providing the Equipment.
4.2.117 Surface

A Surface is a type of Wire_and_surface_element that is a set of connected points in 3D geometric space that is always locally 2D, but need not be a manifold. Surface has many subtypes. Besides being a self-contained object, Surface is used in the definition of other geometric objects such as Point objects and Curve objects. It will not be instantiated as it has no attributes.

4.2.118 Survey_point

A Survey_point is a particular location (position and elevation) on a Site relative to a known geographic location. Survey_point data are established by performing a survey. The collection of Survey_point data can be interpolated to generate a faceted or surface representation of the topography of the Site.

4.2.119 System_space

A System_space is a type of Plant_volume that is used to describe or allocate a volume of space for use by a Plant_system.

4.2.120 Time_unit

A Time_unit is the time period that the data in the file represents.

4.2.121 Torus

A Torus is a type of Csg_element that is defined by sweeping the area of a circle (with minor radius) about a larger circle. A Torus may be a Trimmed_torus.

4.2.122 Trimmed_block

A Trimmed_block is a type of Block that is cut with a plane and one of the two sections of the block is removed.

4.2.123 Trimmed_cone

A Trimmed_cone is a type of Cone that is cut with a plane and one of the resulting sections removed.
4.2.124  **Trimmed_cylinder**

A *Trimmed_cylinder* is a type of *Cylinder* that is cut with a plane and one of the resulting sections removed.

4.2.125  **Trimmed_pyramid**

A *Trimmed_pyramid* is a type of *Pyramid* that is cut with a plane and one of the resulting sections removed.

4.2.126  **Trimmed_sphere**

A *Trimmed_sphere* is a type of *Sphere* that is formed by cutting a sphere with one or more planes and removing some resulting sections.

4.2.127  **Trimmed_torus**

A *Trimmed_torus* is a type of *Torus* that is defined by cutting a torus by one or more planes.

4.2.128  **Tube**

A *Tube* is a type of *Cylinder* that a cylindrical, coaxial shape has been removed from, resulting in a circular opening that passed through the cylinder along its axis.

4.2.129  **Vector**

A *Vector* is a type of *Curve*. It specifies a direction in the 3D space.

4.2.130  **Volume_of_production**

The *Volume_of_production* specifies the number of units to be produced.

4.2.131  **Wire_and_surface_element**

A *Wire_and_surface_element* is a type of *Shape_representation_element* that is composed of geometric elements. Each *Wire_and_surface_element* may be one of the following: a *Curve*, a *Point*, or a *Surface*. 
4.3 Application Assertions
This subsection specifies the application assertions for the plant spatial configuration application protocol. Application assertions specify relationships among application objects, the cardinality of the relationships, and the rules required for the integrity and validity of the application objects and UoFs. The application assertions and their definitions are given below.

4.3.1 Activity_of_the_part to Activity_space_required

Each Activity_of_the_part is estimated as zero, one, or more Activity_space_required objects. Each Activity_space_required is the estimated space of exactly one Activity_of_the_part.

4.3.2 Activity_of_the_part to Operations_on_part

Each Activity_of_the_part has zero, one, or more Operations_on_part objects. Each Operations_on_part defines exactly one Activity_of_the_part.

4.3.3 Activity_of_the_part to Sequence_of_operations

Each Activity_of_the_part contains zero, one, or more Sequence_of_operations objects. Each Sequence_of_operations defines exactly one Activity_of_the_part.

4.3.4 Activity_of_the_part to Material_handling_cost

Each Activity_of_the_part is estimated as zero, one, or more Material_handling_cost objects. Each Material_handling_cost is the estimated cost of exactly one Activity_of_the_part.

4.3.5 Breakline to Survey_point

Each Breakline is defined by one or more Survey_point objects. Each Survey_point defines zero, one, or many Breakline objects.

4.3.6 Building to Location_in_building

Each Building is a reference frame for zero, one, or many Location_in_building objects. Each Location_in_building has a reference frame provided by exactly one Building.

4.3.7 Catalogue_definition to Catalogue_item

Each Catalogue_definition contains zero, one, or many Catalogue_item objects. Each Catalogue_item is contained by exactly one Catalogue_definition.
4.3.8  Catalogue_item to Catalogue_item_substitute

Each Catalogue_item has zero, one, or many Catalogue_item_substitute objects. Each Catalogue_item_substitute identifies a substitute for exactly one Catalogue_item.

Each Catalogue_item is a substitute in zero, one, or many Catalogue_item_substitute objects. Each Catalogue_item_substitute identifies as a substitute exactly one Catalogue_item.

4.3.9  Catalogue_item to Plant_item_definition

Each Catalogue_item is defined by zero, one, or many Plant_item_definition objects. Each Plant_item_definition defines zero, one, or many Catalogue_item objects.

4.3.10  Change to Change_item

Each Change changes one or more Change_item objects. Each Change_item is changed by zero, one, or many Change objects.

4.3.11  Change to Change_life_cycle_stage_usage

Each Change is assigned by one or more Change_life_cycle_stage_usage objects. Each Change_life_cycle_stage_usage assigns exactly one Change.

4.3.12  Change_item to Change_delta

Each Change_item is the changed item from zero, one, or many Change_delta objects. Each Change_delta identifies exactly one Change_item as the item that has been changed.

Each Change_item is the changed to item zero, one, or many Change_delta objects. Each Change_delta identifies exactly one Change_item as the item that is the result of a change.

4.3.13  Change_life_cycle_stage to Change_life_cycle_stage_sequence

Each Change_life_cycle_stage is the predecessor in zero, one, or many Change_life_cycle_stage_sequence objects. Each Change_life_cycle_stage_sequence has exactly one Change_life_cycle_stage as the predecessor.

Each Change_life_cycle_stage is the successor in zero, one, or many Change_life_cycle_stage_sequence objects. Each Change_life_cycle_stage_sequence has exactly one Change_life_cycle_stage as the successor.
4.3.14 Change_life_cycle_stage to Change_life_cycle_stage_usage

Each Change_life_cycle_stage has changes assigned by zero, one, or many Change_life_cycle_stage_usage objects. Each Change_life_cycle_stage_usage assigns changes for exactly one Change_life_cycle_stage.

4.3.15 Change_life_cycle_stage_usage to Change_approval

Each Change_life_cycle_stage_usage is approved by zero, one, or many Change_approval objects. Each Change_approval approves exactly one Change_life_cycle_stage_usage.

4.3.16 Design_project to Project_design_assignment

Each Design_project is performed in one or more Project_design_assignment objects. Each Project_design_assignment assigns a task to exactly one Design_project.

4.3.17 Equipment to Equipment_space_required

Each Equipment is estimated as zero, one, or many Equipment_space_required objects. Each Equipment_space_required is the estimated space of exactly one Equipment.

4.3.18 Equipment to Supplied_equipment

Each Equipment is used as zero, one, or many Supplied_equipment objects. Each Supplied_equipment is exactly one Equipment.

4.3.19 Facet_trigon to Survey_point

Each Facet_trigon is defined by exactly three Survey_point objects. Each Survey_point defines zero, one, or many Facet_trigon objects.

4.3.20 Faceted_surface_representation to Facet_trigon

Each Faceted_surface_representation is composed of one or more Facet_trigon objects. Each Facet_trigon is a component of exactly one Faceted_surface_representation.

4.3.21 Functional_plant to Functional_plant_satisfaction

Each Functional_plant is the functional requirements for zero, one, or many Functional_plant_satisfaction. Each Functional_plant_satisfaction gets the functional requirements from exactly one Functional_plant.
4.3.22  Functional_plant to Plant_system

Each *Functional_plant* is made up of zero, one, or many *Plant_system* objects. Each *Plant_system* is part of exactly one *Functional_plant*.

4.3.23  Functional_design_view to Functional_plant_item_satisfaction

Each *Functional_design_view* is the functional requirements for zero, one, or many *Functional_plant_item_satisfaction*. Each *Functional_plant_item_satisfaction* gets the functional requirements from exactly one *Functional_design_view*.

4.3.24  Material_handling_equipment to Activity_of_the_part

Each *Material_handling_equipment* is used by zero, one, or more *Activity_of_the_part* objects. Each *Activity_of_the_part* uses zero, one, or many *Material_handling_equipment* objects.

4.3.25  Parts_in_product to Part_routing_and_intensity

Each *Parts_in_product* contains zero, one, or more *Part_routing_and_intensity* objects. Each *Part_routing_and_intensity* supports exactly one *Parts_in_product*.

4.3.26  Physical_design_view to Functional_plant_item_satisfaction

Each *Physical_design_view* satisfies requirements for zero, one, or many *Functional_plant_item_satisfaction* objects. Each *Functional_plant_item_satisfaction* has requirements satisfied by exactly one *Physical_design_view*.

4.3.27  Physical_design_view to Installed_physical_design_view

Each *Physical_design_view* is used as zero or one *Installed_physical_design_view*. Each *Installed_physical_design_view* is exactly one *Physical_design_view*.

4.3.28  Planned_physical_plant to Changed_planned_physical_plant

Each *Planned_physical_plant* is changed by zero, one, or many *Changed_planned_physical_plant* objects. Each *Changed_planned_physical_plant* changes exactly one *Planned_physical_plant*.

4.3.29  Planned_physical_plant to Functional_plant_satisfaction

Each *Planned_physical_plant* satisfies requirements for zero, one, or many
*Functional_plant_satisfaction* objects. Each *Functional_plant_satisfaction* has requirements satisfied by exactly one *Planned_physical_plant*.

4.3.30  **Planned_physical_plant to Location_in_plant**

Each *Planned_physical_plant* contains zero, one, or many *Location_in_plant* objects. Each *Location_in_plant* is located in zero, one, or many *Planned_physical_plant* objects.

4.3.31  **Planned_physical_plant to Sited_plant**

Each *Planned_physical_plant* is used as zero or one *Sited_plant*. Each *Sited_plant* is exactly one *Planned_physical_plant*.

4.3.32  **Plant to Changed_plant**

Each *Plant* is changed by zero, one, or many *Changed_plant* objects. Each *Changed_plant* changes exactly one *Plant*.

4.3.33  **Plant to External_classification**

Each *Plant* is classified by zero, one, or many *External_classification* objects. Each *External_classification* classifies zero, one, or many *Plant* objects.

4.3.34  **Plant to Functional_plant**

Each *Plant* is used as zero or one *Functional_plant*. Each *Functional_plant* is exactly one *Plant*.

4.3.35  **Plant to Planned_physical_plant**

Each *Plant* is realized as zero, one, or many *Planned_physical_plant* objects. Each *Planned_physical_plant* is the realization of exactly one *Plant*.

4.3.36  **Plant to Plant_process_capability**

Each *Plant* produces zero, one, or many *Plant_process_capability* objects. Each *Plant_process_capability* is produced by exactly one *Plant*.

4.3.37  **Plant to Sub_plant_relationship**

Each *Plant* contains zero, one, or many *Sub_plant_relationship* objects. Each
Sub_plant_relationship is contained in exactly one Plant.

Each Plant is used in zero, one, or many Sub_plant_relationship objects. Each Sub_plant_relationship uses exactly one Plant.

4.3.38 Plant_item to Changed_plant_item

Each Plant_item is changed by zero, one, or many Changed_plant_item objects. Each Changed_plant_item changes exactly one Plant_item.

4.3.39 Plant_item to External_classification

Each Plant_item is classified by zero, one, or many External_classification objects. Each External_classification classifies zero, one, or many Plant_item objects.

4.3.40 Plant_item to Plant_item_design_view

Each Plant_item is defined as one or more Plant_item_design_view objects. Each Plant_item_design_view defines exactly one Plant_item.

4.3.41 Plant_item to Plant_item_shape

Each Plant_item is spatially described by zero, one, or many Plant_item_shape objects. Each Plant_item_shape spatially describes exactly one Plant_item.

4.3.42 Plant_item to Plant_item_weight

Each Plant_item is measured as having zero, one, or many Plant_item_weight objects. Each Plant_item_weight is the measured weight of exactly one Plant_item.

4.3.43 Plant_item to Reference_geometry

Each Plant_item references zero, one, or many Reference_geometry objects. Each Reference_geometry is referenced by zero, one, or many Plant_item objects.

4.3.44 Plant_item to Required_material_description

Each Plant_item satisfies zero, one, or many Required_material_description objects. Each Required_material_description is satisfied by zero, one, or many Plant_item objects.
4.3.45 Plant_item to Spare_plant_item_usage

Each Plant_item is the primary plant item in zero, one, or many Spare_plant_item_usage objects. Each Spare_plant_item_usage has as a primary plant item exactly one Plant_item.

Each Plant_item is the spare plant item in zero, one, or many Spare_plant_item_usage objects. Each Spare_plant_item_usage has as a spare plant item exactly one Plant_item.

4.3.46 Plant_item_definition to Catalogue_item

Each Plant_item_definition is defined as zero, one, or many Catalogue_item objects. Each Catalogue_item is used as zero, one, or many Plant_item_definition objects.

4.3.47 Plant_item_definition to Planned_physical_plant_item

Each Plant_item_definition defines zero, one, or many Planned_physical_plant_item objects. Each Planned_physical_plant_item is defined by zero or one Plant_item_definition.

4.3.48 Plant_item_instance to Plant_item_interference

Each Plant_item_instance is the first item in zero, one, or many Plant_item_interference objects. Each Plant_item_interference has as its first item exactly one Plant_item_instance.

Each Plant_item_instance is the second item in zero, one, or many Plant_item_interference objects. Each Plant_item_interference has as its second item exactly one Plant_item_instance.

4.3.49 Plant_item_instance to Plant_item_location

Each Plant_item_instance is located by zero, one, or many Plant_item_location objects. Each Plant_item_location locates exactly one Plant_item_instance. A Plant_item_instance shall be located only once in either a plant, site, or building or multiple times with respect to other Plant_item objects. A Plant_item_instance shall not be located more than once in a plant, site, or building.

4.3.50 Plant_item_instance to Project_design_assignment

Each Plant_item_instance is assigned a project by zero, one, or many Project_design_assignment objects. Each Project_design_assignment assigns a project to exactly one Plant_item_instance.
4.3.51  Plant_item_instance to Relative_item_location

Each Plant_item_instance is the referenced item for zero, one, or many Relative_item_location objects. Each Relative_item_location references exactly one Plant_item_instance.

4.3.52  Plant_item_interference to Interfering_shape_element

Each Plant_item_interference has intersecting geometry of zero, one, or many Interfering_shape_element objects. Each Interfering_shape_element is the intersecting geometry for exactly one Plant_item_interference.

4.3.53  Plant_item_interference to Plant_item_interference_status

Each Plant_item_interference has a status of one or more Plant_item_interference_status objects. Each Plant_item_interference_status provides the status for exactly one Plant_item_interference.

4.3.54  Plant_item_interference to Shape_interference_zone_usage

Each Plant_item_interference has a zone of interference defined by zero, one, or many Shape_interference_zone_usage objects. Each Shape_interference_zone_usage defines the zone of interference for exactly one Plant_item_interference.

4.3.55  Plant_item_location to Changed_plant_item_location

Each Plant_item_location is changed by zero, one, or many Changed_plant_item_location objects. Each Changed_plant_item_location changes exactly one Plant_item_location.

4.3.56  Plant_item_shape to Changed_plant_item_shape

Each Plant_item_shape is changed by zero, one, or many Changed_plant_item_shape objects. Each Changed_plant_item_shape changes exactly one Plant_item_shape.

4.3.57  Plant_item_shape to Shape_representation

Each Plant_item_shape is defined using zero, one, or many Shape_representation objects. Each Shape_representation defines exactly one Plant_item_shape.

4.3.58  Plant_process_capability to Changed_plant_process_capability

Each Plant_process_capability is changed by zero, one, or many
Changed_plant_process_capability objects. Each Changed_plant_process_capability changes exactly one Plant_process_capability.

4.3.59 Plant_system to Changed_plant_system

Each Plant_system is changed by zero, one, or many Changed_plant_system objects. Each Changed_plant_system changes exactly one Plant_system.

4.3.60 Plant_system to External_classification

Each Plant_system is classified by zero, one, or many External_classification objects. Each External_classification classifies zero, one, or many Plant_system objects.

4.3.61 Plant_system to Plant_item

Each Plant_system is composed of zero, one, or many Plant_item objects. Each Plant_item is part of zero, one, or many Plant_system objects.

4.3.62 Plant_system to Plant_system_assembly

Each Plant_system is the sub-system in zero, one, or many Plant_system_assembly objects. Each Plant_system_assembly has exactly one Plant_system as the sub-system.

Each Plant_system is the super-system in zero, one, or many Plant_system_assembly objects. Each Plant_system_assembly has exactly one Plant_system as the super-system.

4.3.63 Point_and_line_representation to Survey_point

Each Point_and_line_representation is defined by one or more Survey_point objects. Each Survey_point defines zero, one, or many Point_and_line_representation objects.

4.3.64 Reference_geometry to Changed_reference_geometry

Each Reference_geometry is changed by zero, one, or many Changed_reference_geometry objects. Each Changed_reference_geometry changes exactly one Reference_geometry.

4.3.65 Reference_geometry to Shape_representation_element

Each Reference_geometry is described by zero, one, or many Shape_representation_element objects. Each Shape_representation_element provides description for zero, one, or many Reference_geometry objects.
4.3.66  Required_material_description to Changed_required_material_description

Each Shape_representation_element is changed by zero, one, or many
Changed_required_material_description objects. Each
Changed_required_material_description changes exactly one Shape_representation_element.

4.3.67  Required_material_description to Material_specification_selection

Each Required_material_description is satisfied by zero, one, or many
Material_specification_selection objects. Each Material_specification_selection satisfies zero,
one, or many Required_material_description objects.

4.3.68  Shape_representation to Shape_representation_element_usage

Each Shape_representation is defined by one or more Shape_representation_element_usage
objects. Each Shape_representation_element_usage defines exactly one Shape_representation.

4.3.69  Shape_representation_element to Shape_interference_zone_usage

Each Shape_representation_element defines a volume for zero or one
Shape_interference_zone_usage. Each Shape_interference_zone_usage has a volume defined
by exactly one Shape_representation_element.

4.3.70  Shape_representation_element to Shape_representation_element_usage

Each Shape_representation_element provides a definition for zero or one
Shape_representation_element_usage. Each Shape_representation_element_usage uses as a
definition exactly one Shape_representation_element.

4.3.71  Shape_representation_element_usage to Interfering_shape_element

Each Shape_representation_element_usage is the intersecting geometry of zero, one, or many
Interfering_shape_element objects. Each Interfering_shape_element uses as intersecting
geometry exactly one Shape_representation_element_usage.

4.3.72  Site to Building

Each Site has located on it zero, one, or many Building objects. Each Building is located on
exactly one Site.
4.3.73  Site to Changed_site

Each Site is changed by zero, one, or many Changed_site objects. Each Changed_site changes exactly one Site.

4.3.74  Site to Location_in_site

Each Site is a reference frame for zero, one, or many Location_in_site objects. Each Location_in_site has a reference frame provided by exactly one Site.

4.3.75  Site to Site_feature

Each Site contains zero, one, or many Site_feature objects. Each Site_feature object is contained in exactly one Site.

4.3.76  Site to Site_shape_representation

Each Site has shape defined by zero, one, or many Site_shape_representation objects. Each Site_shape_representation defines the shape of exactly one Site.

4.3.77  Site to Sited_plant

Each Site has located on it one or more Sited_plant objects. Each Sited_plant is located on exactly one Site.

4.3.78  Site_feature to Changed_site_feature

Each Site_feature is changed by zero, one, or many Changed_site_feature objects. Each Changed_site_feature changes exactly one Site_feature.

4.3.79  Site_shape_representation to Breakline

Each Site_shape_representation is constrained by zero, one, or many Breakline objects. Each Breakline constrains zero or one Site_shape_representation.

4.3.80  Site_shape_representation to Gis_position

Each Site_shape_representation has a global position specified by zero or one Gis_position. Each Gis_position specifies the global position for exactly one Site_shape_representation.
4.3.81 Sited_plant to Changed_sited_plant

Each Sited_plant is changed by zero, one, or many Changed_sited_plant objects. Each Changed_sited_plant changes exactly one Sited_plant.

4.3.82 Sub_plant_relationship to Changed_sub_plant_relationship

Each Sub_plant_relationship is changed by zero, one, or many Changed_sub_plant_relationship objects. Each Changed_sub_plant_relationship changes exactly one Sub_plant_relationship.

4.3.83 Supplier to Catalogue_definition

Each Supplier publishes zero, one, or many Catalogue_definition objects. Each Catalogue_definition is published by zero or one Supplier.

4.3.84 Supplier to Supplied_equipment

Each Supplier supplies one or more Supplied_equipment objects. Each Supplied_equipment is supplied by exactly one Supplier.
ANOTATED BIBLIOGRAPHY
This section presents a bibliography that lists key technical references with a short paragraph summary of each reference.

The book provides a demonstration of the ordered planning necessary for efficient material flow and the preparation of effective layout for requisite physical facilities. While the principal focus is toward the industrial establishment, recognition is given throughout to the applicability of procedures and techniques in other areas, and to the adaptability of the approaches and methods to the planning of any facility such as library, or campus.

The document represents the first step toward the goal of the Systems Integration of Manufacturing Applications (SIMA) architecture project -- to identify the functions and interfaces required of manufacturing applications software systems. The reference architecture has three parts: the activity model, the system model, and the information model. This document describes the activity model.

The book was written for the working group of the International Federation of Information Processing (IFIP) that is concerned with the automation of production management and other related subjects. The Production Control deals with “the material supply and processing activities of an enterprise.” The terms used in Production Control depend in part on the conceptual framework accepted for the subject.

The intended audience of this book is students in courses which address facility layout and location. Several mathematical models were proposed in the book as an aid to solving layout and location problems.

The document presents initial result from NIST’s Rapid Response Manufacturing (RRM) Project effort to develop a proposed representation of manufacturing resource data. The document contains technical requirements to describe the information categories, attributes, and relationships for use in development of a common representation.

The book provides the reader with methods for developing an optimum plant layout. It offers a
step-by-step guide to planning new factories and plant rearrangements.

The book presents the processes of manufacturing. Primary processes and secondary processes are two major types of manufacturing processes. Primary processing changes raw materials into standard industrial stock, while secondary processing changes standard stock into useful finished products.
APPENDIX: Application Software Review

This section identifies factory planning simulation and animation software packages for which interface requirements may be relevant to this IMES. The identification of the commercial software packages, however, does not imply recommendation or endorsement by the National Institute of Standards and Technology.

<table>
<thead>
<tr>
<th>SOFTWARE</th>
<th>VENDOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARCHIBUS/FM (V.10.0)</td>
<td>ARCHIBUS, Inc., MA</td>
</tr>
<tr>
<td>Arris Facilities Planning</td>
<td>Sigma Design International, LLC, LA</td>
</tr>
<tr>
<td>AutoCAD</td>
<td>Autodesk, Inc., CA</td>
</tr>
<tr>
<td>AutoSched, AutoMOD, the Simulator</td>
<td>AutoSimulations, Inc., UT</td>
</tr>
<tr>
<td>ERGO, IGRIP, QUEST</td>
<td>Deneb Robotics, Inc., MI</td>
</tr>
<tr>
<td>FactoryCAD, FactoryFLOW, FactoryPLAN</td>
<td>Cimtechnologies Corp., IA</td>
</tr>
<tr>
<td>LayOPT (V.1.0)</td>
<td>Production Modeling Corp., MI</td>
</tr>
<tr>
<td>MALAGA</td>
<td>ZIP, Ingenieurburo Industrieplanung Und Organisation, Munich</td>
</tr>
<tr>
<td>Pro/ENGINEER</td>
<td>Parametric Technology Corp., MA</td>
</tr>
<tr>
<td>Project Layout</td>
<td>Intergraph Corp., AL</td>
</tr>
<tr>
<td>Soft Assembly</td>
<td>SILMA, Inc., CA</td>
</tr>
<tr>
<td>Transom Jack</td>
<td>Transom Technologies, Inc., MI</td>
</tr>
</tbody>
</table>