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

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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

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1. Howe, S., "High Performance Computing and Communications: Toward a National Information Infrastructure," Government Printing Office, Washington, DC, 1994.
2. Edited by Barkmeyer, E., Hopp, T., Pratt, M., and Rinaudot, G., "Background Study: Requisite Elements, Rationale, and Technology Overview for the Systems Integration for Manufacturing Applications (SIMA) Program," NISTIR 5662, National Institute of Standards and Technology, Gaithersburg, MD, September 1995.
3. Kemmerer, S. and Fowler, J., "Initial Manufacturing Exchange Specification (IMES): IMES Concept Document for Manufacturing Systems Integration," NISTIR 5978, National Institute of Standards and Technology, Gaithersburg, MD, February 1997.

specification.

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[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

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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[1]. 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[2] 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

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1. International Organization for Standardization, "Industrial automation systems and integration - Product data representation and exchange - Part 227: Application Protocol: Plant Spatial Configuration", ISO/CD 10303-227, 1995.
2. "Integrated Computer-Aided Manufacturing (ICAM) Functional Modeling Manual (IDEF0)", UM 110231100, Material Laboratory, U.S. Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, OH, June 1981.

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.

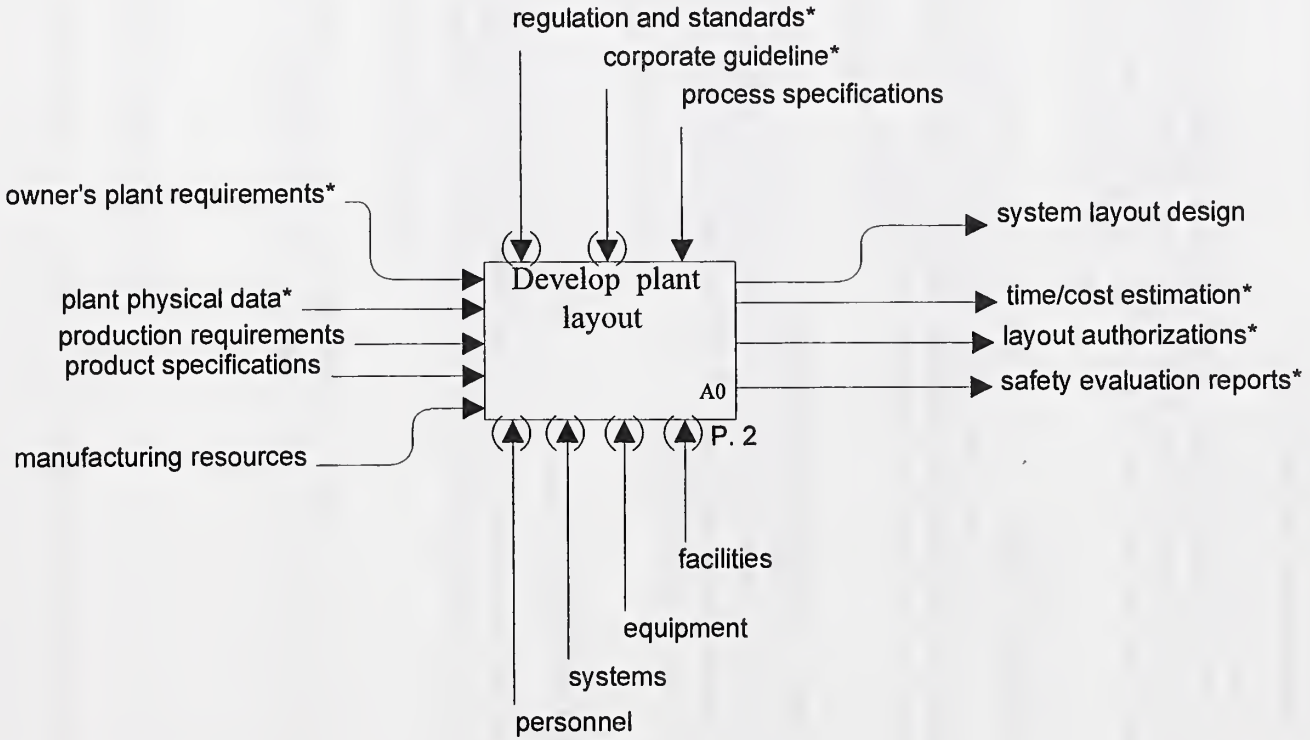
1.1.1.40 Time/cost estimation* (ICOM)

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.

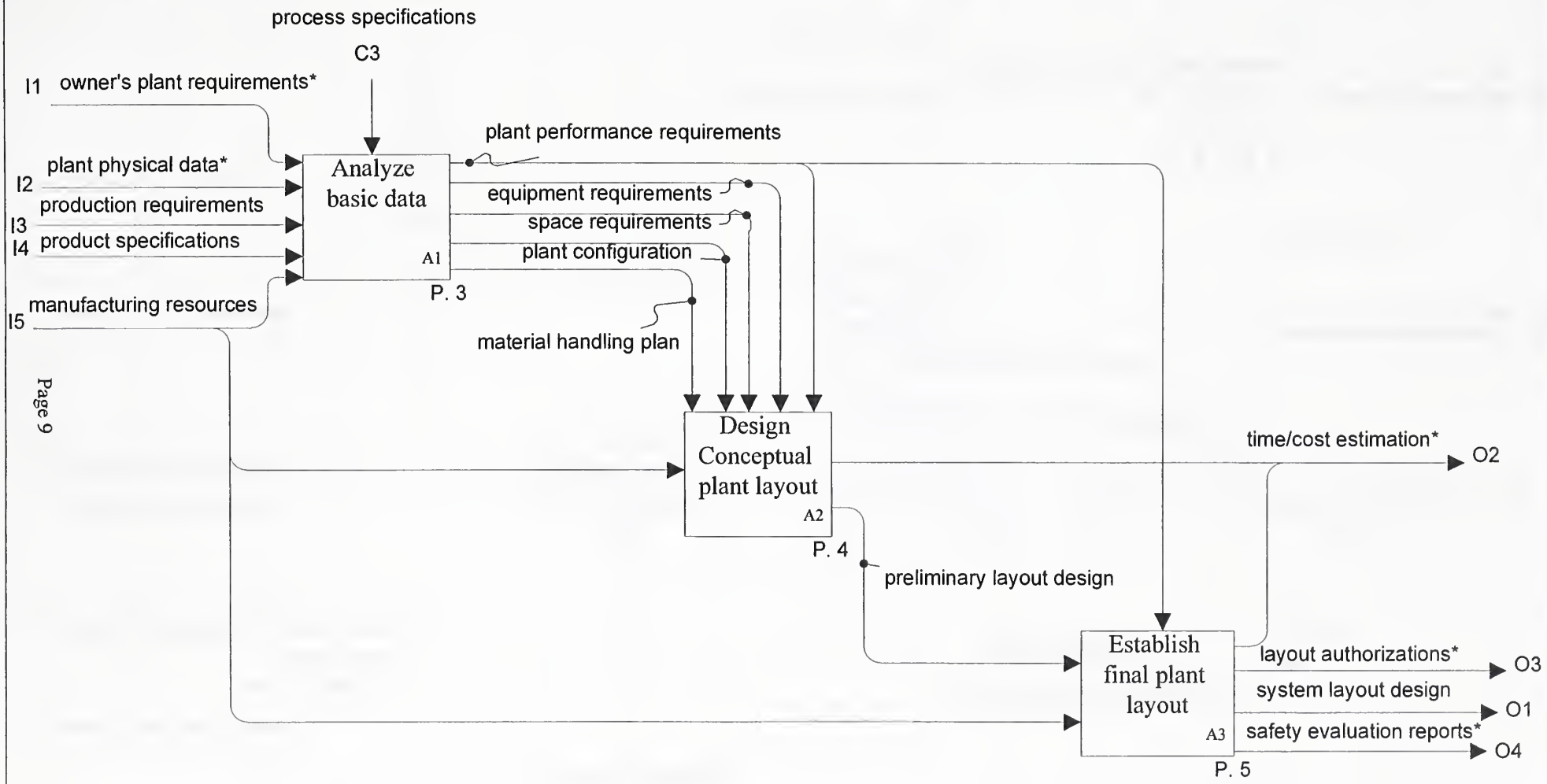
USED AT:	AUTHOR: Y. Tina Lee	DATE: 06/29/98		WORKING	READER DATE	CONTEXT:
	PROJECT: SIMA - Plant Layout	REV:	x	DRAFT		Top
	NOTES: 1 2 3 4 5 6 7 8 9 10			RECOMMENDED		
				PUBLICATION		



Data flows that are out of scope are marked with asterisks.

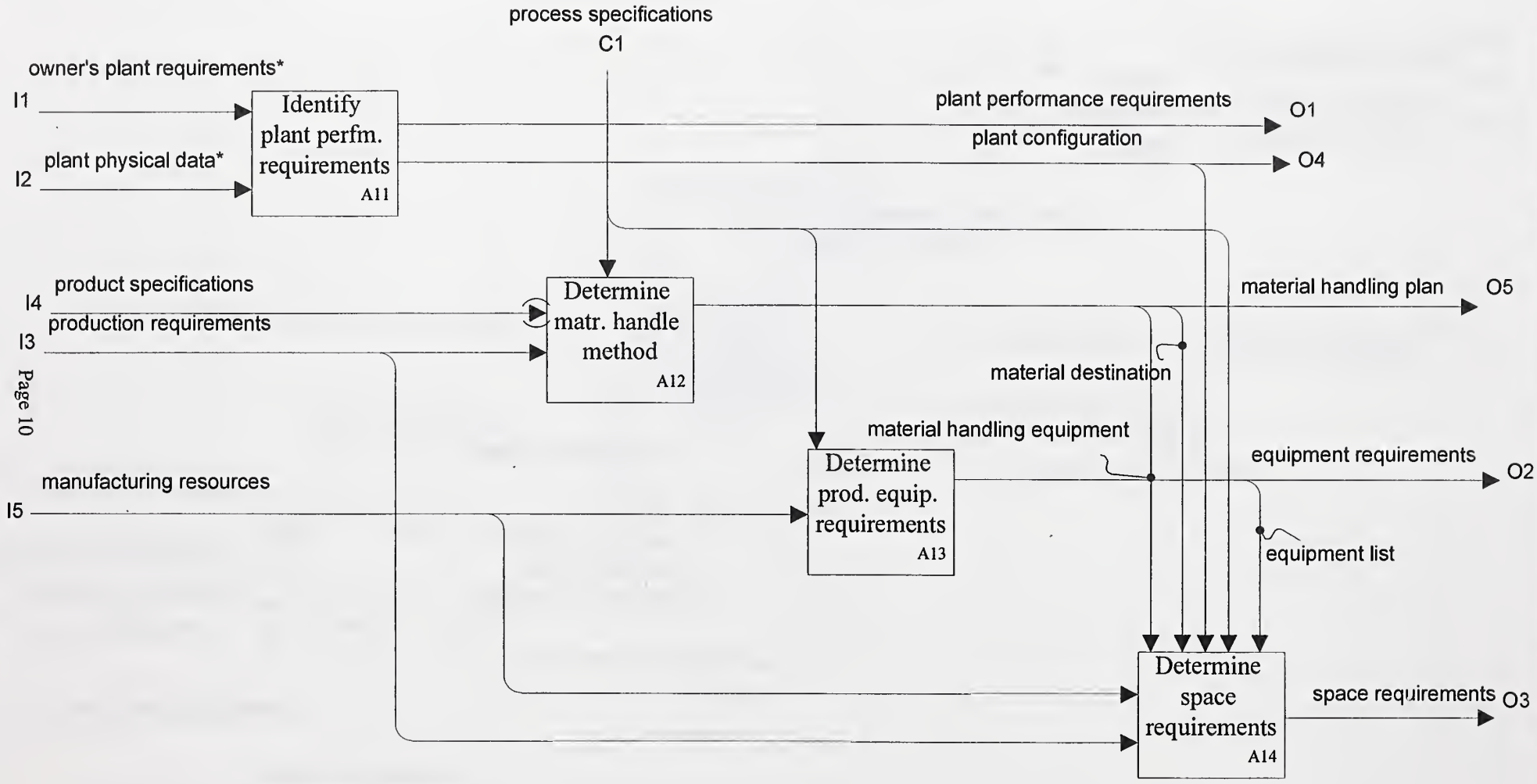
NODE: A-0	TITLE:	NUMBER: P. 1

USED AT:	AUTHOR:	DATE: 06/29/98	x	WORKING	READER	DATE	CONTEXT:
	PROJECT:	REV:		DRAFT			
	NOTES: 1 2 3 4 5 6 7 8 9 10			RECOMMENDED			
				PUBLICATION			



NODE: A0	TITLE: Develop plant layout	NUMBER: P. 2

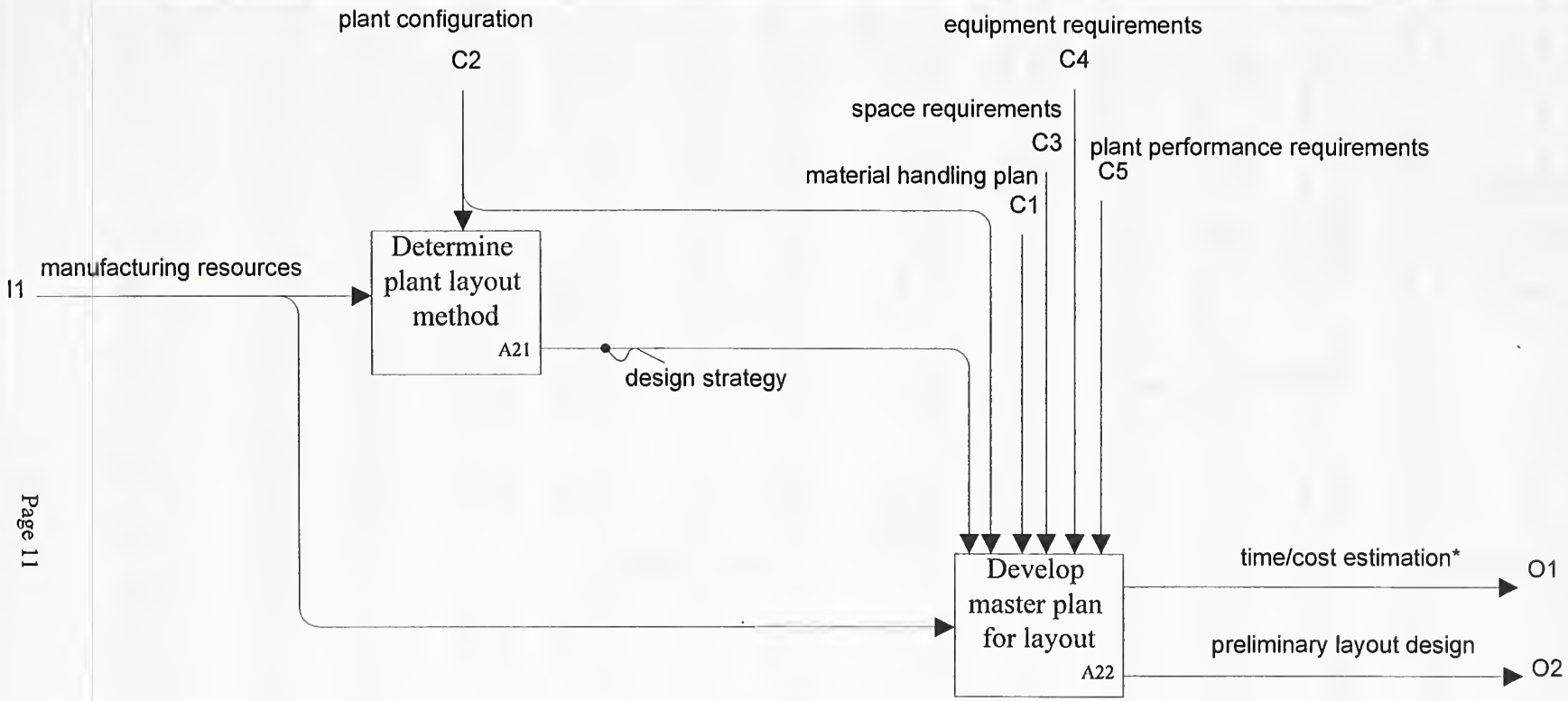
USED AT:	AUTHOR:	DATE: 06/29/98	x	WORKING	READER	DATE	CONTEXT:
	PROJECT:	REV:		DRAFT			
	NOTES: 1 2 3 4 5 6 7 8 9 10			RECOMMENDED			
				PUBLICATION			



Page 10

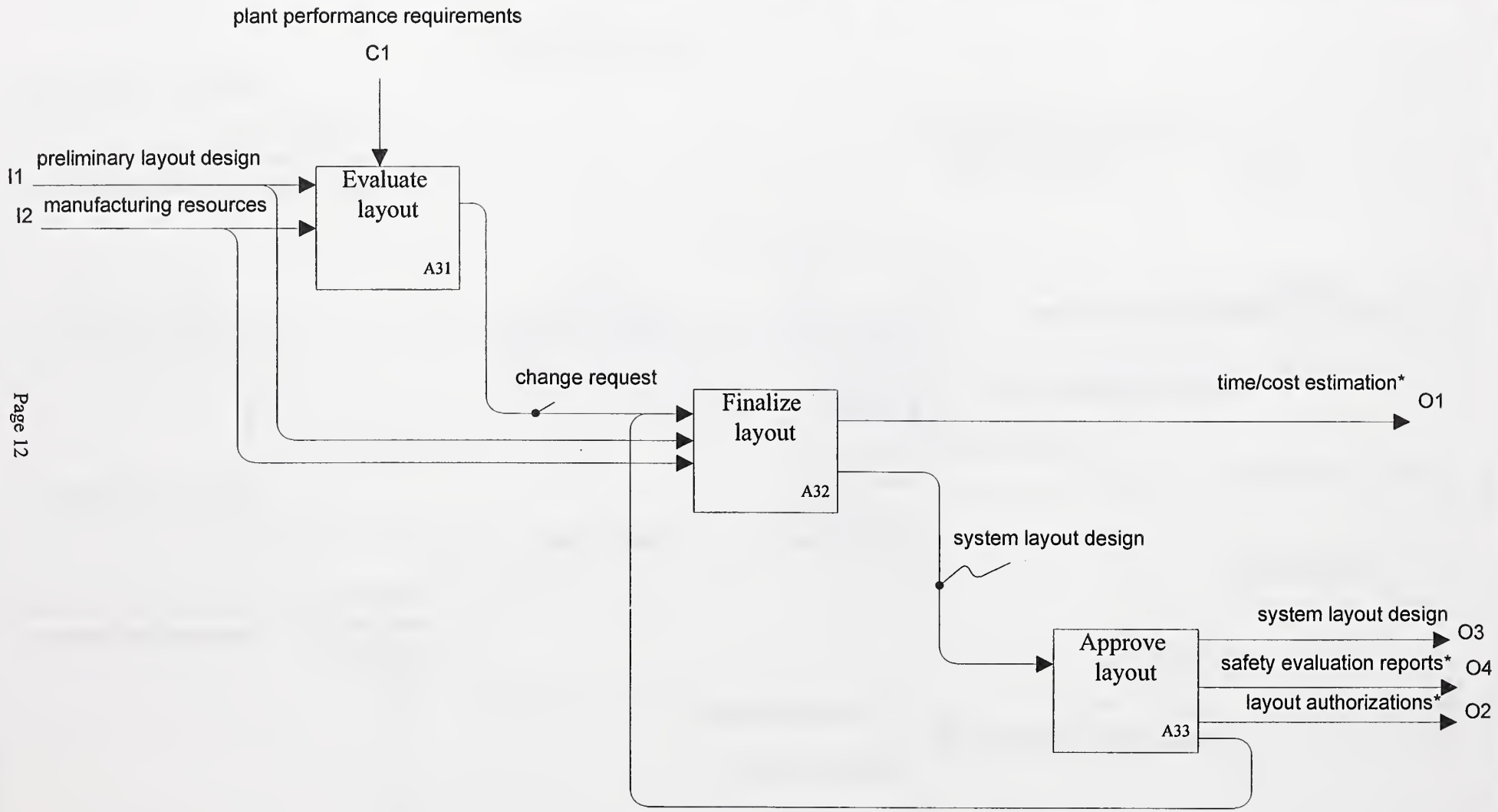
NODE: A1	TITLE: Analyze basic data	NUMBER: P. 3

USED AT:	AUTHOR:	DATE: 06/29/98	x	WORKING	READER	DATE	CONTEXT:
	PROJECT:	REV:		DRAFT			
	NOTES: 1 2 3 4 5 6 7 8 9 10			RECOMMENDED			
				PUBLICATION			



NODE: A2	TITLE: Design Conceptual plant layout	NUMBER: P. 4

USED AT:	AUTHOR:	DATE: 06/29/98	x	WORKING	READER	DATE	CONTEXT:
	PROJECT:	REV:		DRAFT			
	NOTES: 1 2 3 4 5 6 7 8 9 10			RECOMMENDED			
				PUBLICATION			



NODE: A3	TITLE: Establish final plant layout	NUMBER: P. 5

2 STANDARDS REVIEW

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.

ISO 8824-1:1994, Information technology - Open systems interconnection - Abstract syntax notation one (ASN.1) - Part 1: Specification of basic notation.

ISO 10303-1:1994, Industrial automation systems and integration - Product data representation and exchange - Part 1: Overview and fundamental principles.

ISO 10303-11:1994, Industrial automation systems and integration - Product data representation and exchange - Part 11: Description methods: The EXPRESS language reference manual.

ISO 10303-21:1994, Industrial automation systems and integration - Product data representation and exchange - Part 21: Implementation methods: Clear text encoding of the exchange structure.

ISO 10303-31:1994, Industrial automation systems and integration - Product data representation and exchange - Part 31: Conformance testing methodology and framework: General concepts.

ISO 10303-41:1994, Industrial automation systems and integration - Product data representation and exchange - Part 41: Integrated generic resources: Fundamentals of product description and support.

ISO 10303-42:1994, Industrial automation systems and integration - Product data representation and exchange - Part 42: Integrated generic resources: Geometric and topological representation.

ISO 10303-43:1994, Industrial automation systems and integration - Product data representation and exchange - Part 43: Integrated generic resources: Representation structures.

ISO 10303-44:1994, Industrial automation systems and integration - Product data representation and exchange - Part 44: Integrated generic resources: Product structure configuration.

ISO/FDIS 10303-45, Industrial automation systems and integration - Product data representation and exchange - Part 45: Integrated generic resources: Material, 1997.

ISO 10303-46:1994, Industrial automation systems and integration - Product data representation and exchange - Part 46: Integrated generic resources: Visual presentation.

ISO/FDIS 10303-47:1997 Industrial automation systems and integration - Product data representation and exchange - Part 47: Integrated generic resources: Shape variation tolerances, 1997.

ISO/CD 10303-227, Industrial automation systems and integration - Product data representation and exchange - Part 227: Application Protocol: Plant Spatial Configuration, 1995.

3 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;
    - unilateral 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

CSG	Constructive Solid Geometry
HPCC	High Performance Computing and Communication program
HVAC	Heating, Ventilation, and Air Conditioning
ICAM	The U.S. Air Force's Integrated Computer Aided Manufacturing Program
ICOM	Data /Objects of Inputs, Controls, Outputs, or Mechanisms to the IDEF0 Activity
IDEF	ICAM Definition Method
ID	Identifier
IFIP	International Federation for Information Processing
IMES	Initial Manufacturing Exchange Specifications
ISO	International Organization for Standardization
NIST	National Institute of Standards and Technology
PDM	Product Data Management
SIMA	NIST's System Integration of Manufacturing Applications Program
STEP	Standard for the Exchange of Product Model Data
UoF	Unit of Functionality

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;
- Material_specification_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;

- Plant;
- Plant_system;
- Plant_system_assembly;
- Sub_plant_relationship.

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_shap* 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;

- Product_specification;
- Production_rate;
- Time_unit;
- Volume_of_production.

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_deccription

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_numbe*r 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 C*hange_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 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;
- distance_moved;
- 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_assemby

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:

- type.

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 is 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 more *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*.

ANNOTATED BIBLIOGRAPHY

This section presents a bibliography that lists key technical references with a short paragraph summary of each reference.

James M. Apple, "Plant Layout and Material Handling," Third Edition, John Wiley &Sons, New York/Chichester/Brisbane/Toronto, 1977.

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.

Edward J. Barkmeyer (Editor), "SIMA Reference Architecture Part1: Activity Models," NISTIR 5939, National Institute of Standards and Technology, Gaithersburg, MD, 1996.

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.

John L. Burbidge, "IFIP Glossary of Terms Used in Production Control," Elsevier Science Publishers B.V., 1987.

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.

Richard L. Francis, Leon F. McGinnis Jr., and John A. White, "Facility Layout and Location: An Analytical Approach," Second Edition, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1992.

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.

Kevin K. Jurrens, James E. Fowler, Mary Elizabeth A. Algeo, "Modeling of Manufacturing Resource Information," NISTIR 5707, National Institute of Standards and Technology, Gaithersburg, MD, 1995.

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.

Edward J. Phillips, "Manufacturing Plant Layout," Second Edition, Society of Manufacturing Engineers, Dearborn, MI, 1997.

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.

R. Thomas Wright, "Processes of Manufacturing," The Goodheart-Willcox Company, Inc., South Holland, IL., 1990.
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.

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