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Enterprise-control system integration —

Part 2:
Objects and attributes for enterprise-control system integration

Intégration des systèmes entreprise-contrôle —

Partie 2: Objets et attributs pour l'intégration des systèmes de commande d'entreprise

This draft is submitted to a parallel vote in ISO and in IEC.

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Enterprise-Control System Integration - Part 2: Object models and relationships for interfaces between manufacturing operations and business functions

FOREWORD

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IEC 62264-2 has been prepared by subcommittee 65E: Devices and integration in enterprise systems, of IEC technical committee 65: Industrial-process measurement, control, and automation. It is an International Standard.

This document is based upon IEC CD 62264-2 and ANSI/ISA 95.00.02-2018 (ED3), Enterprise-Control System Integration, Part 2: Objects and Attributes for Enterprise-Control System Integration. It is used with the permission of the copyright holder, the Instrumentation, Systems and Automation Society (ISA).

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This third edition cancels and replaces the second edition published in 2013. This edition constitutes a technical revision. Due to the extent of the changes and updates, this document cannot ensure backward compatibility to implementations based on older editions. This edition includes the following significant technical changes with respect to the previous edition and ANSI/ISA 95.00.02-2018 (ED3):

a) object models are added for the use of interactive communications to notify subscribers about the occurrence of events and to provide context information about the event, making the information exchange more efficient and consistent. The added object models were the operations event model and operations record model.

b) operations location model and spatial definition attribute added to allow the description of operation locations.

c) operations test model added to define how test specifications and test results are related to testable objects, operations test requirements, actual resource, and work definitions.

d) definition of possible measurement uncertainty sub-attributes for all value, quantity and duration attributes defined in this document.

e) updated hierarchy scope model.

f) removed as separate models in this edition were the models for product definition, production schedule, production performance, and production capability. Their content is covered for all manufacturing operations management categories under operations models.

g) object model was added for the operations segment capability as a collection of resources related to other operations models.

h) updated relationship name and role name conventions established in 3.3.4 and implemented across all models and associated tables.

i) updated all objects' relationship role table with explicit source and target names.

j) updated common header attributes for objects and property objects established in 4.5 and implemented across all models and associated tables.

k) updated explanation of the 'relationships between resource reference objects in operations management information models and resource models. These additional resource relationships are added to all operations management models.

l) added an annex explanation for implementation options for specifying values in unit of measurement attribute.

m) added an annex explanation for implementation considerations for inheritance and persistence of data exchange object models.

The text of this International Standard is based on the following documents:

Draft	Report on voting
65E/XX/FDIS	65E/XX/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The list of all the parts of the IEC 62264 series, under the general title *Enterprise-Control system integration*, can be found on the IEC website.

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The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

– reconfirmed,
– withdrawn, or
– revised.

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INTRODUCTION

IEC 62264 is a multi-part standard that defines the interface content between enterprise activities and control activities. This part of IEC 62264 further defines formal object models for exchange information described in IEC 62264-1 using UML object models, tables of attributes, and examples. The models and terminology defined in this document:

a) emphasize good integration practices of control systems with enterprise systems during the entire life cycle of the systems;

b) can be used to improve existing integration capability of manufacturing control systems with enterprise systems;

c) can be applied regardless of the degree of automation; and

d) can be used as a basis for new developments in Smart Manufacturing and Industrie 4.0 initiatives.

Specifically, this document provides a standard terminology and a consistent set of concepts and models for integrating control systems with enterprise systems that will improve communications between all parties involved. Benefits produced will:

e) reduce the user's time to reach full production levels for new products;

f) enable vendors to supply appropriate tools for implementing integration of control systems to enterprise systems;

g) enable users to better identify their needs;

h) reduce the cost of automating manufacturing processes;

i) optimize supply chains; and

j) reduce life-cycle engineering efforts.

This document can be used to reduce the effort associated with implementing new product offerings. The goal is to have enterprise systems and control systems that interoperate and easily integrate.

It is not the intent of the standard to:

k) suggest that there is only one way of implementing integration of control systems to enterprise systems;

l) force users to abandon their current way of handling integration; or

m) restrict development in the area of integration of control systems to enterprise systems.

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1 Scope

This part of IEC 62264 specifies interface content exchanged between manufacturing control functions and other enterprise functions as interrelated information models. The information models are represented as an interrelated collection of conceptual object models which can be used for the implementation of applications with logical data and physical data models. The data exchanges in interfaces are scoped as between Level 3 manufacturing operations and Level 4 business systems in the hierarchical model defined in IEC 62264-1. The purpose of this document is to reduce the risk, cost, and errors associated with interface implementation.

Since this document covers many manufacturing operations and enterprise domains and there are many different standards for those domains, the semantics of this data exchange standard are described at a conceptual level intended to enable the other standards to be mapped to these semantics. To this end, this document defines a set of elements contained in the generic interface, together with a mechanism for extending the interface content for implementations.

The scope is limited to the definition of object models and attributes of the exchanged information defined in the IEC 62264-1.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62264-1:2013, *Enterprise-control system integration - Part 1: Models and terminology*

IEC 62474, *Material declaration for products of and for the electrotechnical industry*

ISO/IEC 19501, *Information technology - Open Distributed Processing - Unified Modeling Language (UML) Version 1.4.2*

ISO/IEC 19505-1, *Information technology - Object Management Group Unified Modeling Language (OMG UML) - Part 1: Infrastructure*

ISO/IEC 19505-2, *Information technology - Object Management Group Unified Modeling Language (OMG UML) - Part 2: Superstructure*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 99:2007, *International vocabulary of metrology - Basic and general concepts and associated terms (VIM)*

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

ISO 15000-5, *Electronic Business Extensible Markup Language (ebXML) - Part 5: Core Components Specification (CCS)*

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3 Terms, definitions, abbreviated terms and conventions

3.1 Terms, definitions and abbreviated terms

For the purposes of this document, the terms, definitions, and abbreviated terms given in IEC 62264-1, as well as the following apply. Specific object models defined in the normative text of this document are not included in this clause.

NOTE This document does not clarify the terms and definitions for notification, alert, and alarm since their application and definition differ by industry in their use in industry-specific standards.

3.1.1
attribute
information, data, or properties that are part of the definition of an object and are represented by a value or a range of values

3.1.2
by-product
secondary material, produced as a residual of, or incidental to the production process

3.1.3
class
logical grouping of objects with similar characteristics as defined in the object's properties

3.1.4
co-product
planned product typically produced in conjunction with a main planned product per the material master because of product or process similarities

3.1.5
event
representation of a solicited or unsolicited fact indicating a change of relevance to Level 3 activities or Level 4 activities

3.1.6
product
desired output of an operations process

Note 1 to entry: A product can be an intermediate product or end product from a business perspective.

Note 2 to entry: Product also defined in ISO 10303-1 as a substance produced by a natural or artificial process.

Note 3 to entry: Product can include by-products and co-products.

3.1.7
property
implementation of specific characteristics of an object

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3.2 Abbreviated terms

For purposes of this document, the following abbreviations apply:

B2MML	business to manufacturing markup language
BOR	bill of resources
CE	common era
EBNF	Extended Backus-Naur Form
EPSG	European Petroleum Survey Group
FQN	fully qualified name
GUID	globally unique identifier
ID	identifier, object identification
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
MIMOSA	machinery information management open systems alliance (original); operations and maintenance information open system alliance (current)
MOM	manufacturing operations management
SOC	standard operating conditions
SOP	standard operating procedure
SRID	spatial reference identifier
UML	unified modeling language
XML	Extensible Markup Language
XSD	XML schema definition

3.3 Conventions

3.3.1 General

Each information object model in this document is depicted using a combination of

a) an object model using a simplified application of the Unified Modeling Language (UML) notational methodology as defined in ISO/IEC 19501,

b) a relationship table for relationship definitions of graphical object model,

c) a relationship role table for the semantic definitions of the relationships,

d) an object attribute table for object attribute and property definitions.

The relationships between objects in different information models are shown in the object model, relationship table, and relationship role table of each information model.

The information models provided in IEC 62264 apply formalism to the description of a problem domain without constraining how the descriptions are mapped to an actual implementation in software. There are many mappings of the information models. Such mappings are called data models, irrespective of whether they are object models (e.g. using UML), entity relationship models or XML schemas. The object model is object-oriented.

NOTE For details on information modeling lifecycle, refer to “Information Modeling: From design to implementation”, Y. Tina Lee (1999), Manufacturing Systems Integration Division. National Institute of Standards and Technology, Gaithersburg, MD 20899-0001, U.S.A [15].

Defined names of objects used in exchanged data are in Italics font, beyond the use defined in ISO/IEC Directives Part 2, to emphasize the specific meaning of terminology of this document.

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3.3.2 Conceptual object model vs. logical data model and physical data models for implementation

The information models of this part and IEC 62264-4 are conceptual object models that are represented graphically in object models using UML models and definition tables to define:

a) resource and operations management objects,

b) object attributes,

c) relationships and roles between objects, and

d) relationships and roles between objects in different information models.

An object model is a conceptual data model of the structure of data. An object model does not provide information related to how the structure shall be implemented or on the means (rules, technologies) of how the structure shall be implemented.

NOTE 1 In an implementation, object models can be represented as a logical data model in schema for the specific purpose to formally document the instance data contents of the conceptual object data models, object names, and structure.

NOTE 2 Object model life cycles are not applicable to individual information exchanges. The relationships in and between the object models provide a view into object lifecycles at the time of an information exchange.

NOTE 3 Per ANSI/X3/SPARC Study Group on Data Base Management Systems; Interim Report, data modeling involves the following levels of abstraction:

a) conceptual data model: the semantics of a domain describing the scope of the information model. This consists of entity classes, representing kinds of things or objects of significance in the domain scope, and relationship assertions about associations between entity classes (objects). A conceptual schema specifies the kinds of facts or propositions that can be expressed using the object model. In that sense, it defines the allowed expressions in an artificial 'language' with a scope that is limited by the scope of the information model.

b) logical data model: the semantics of the information model represented by a particular data manipulation technology. This consists of descriptions of tables and columns, object-oriented classes, and XML tags, among other things.

c) physical data model: the physical means by which data for the information model semantics are stored. This is concerned with partitions, CPUs, tablespaces, and the like.

Conceptual object models differ from the logical and physical data models that are typically used by system and integration design groups in application development. Logical and physical data models in application development focus on a specific target application and implementation method. Conceptual object models are generic models applied across many industries, applications, and implementation methods. As such, the IEC 62264 conceptual information models are focused on being abstract and generic with limited constraints on the representation. Constraints and application requirements are applied during the transformation from conceptual model to logical and physical data models as an implementation model for a specific exchange technology.

3.3.3 UML notation in object models

The object models are depicted using a simplified application of the Unified Modeling Language (UML) notational methodology, as defined in ISO/IEC 19501, ISO/IEC 19505-1 and ISO/IEC 19505-2. For implementations, the user shall consult the referenced document to apply this document.

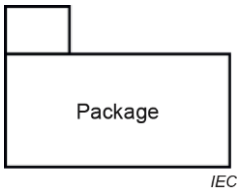
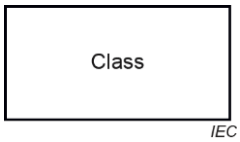
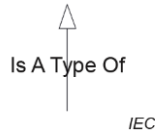
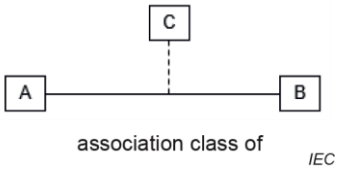
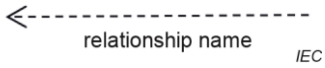
The IEC 62264 simplified UML notation defined in Table 1 is used for depicting object models.

In this document, the word “class” used as part of an object name is a logical grouping, not as a “class” object or structure as used the UML specification.

EXAMPLE 1 The *personnel class* object is considered a “grouping of *person* objects” in the sense of distinguishing between the kinds of personnel in the real world.

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Table 1 – Simplified UML symbols and notation used in object models

Symbol / Notation	Definition
	Defines a package, a collection of IEC 62264 object models. Packages are general-purpose grouping mechanisms used to semantically organize related object model elements as object attributes and object-to-object relationships. In this document, a package is used to specify an external model, such as the external Level 4 ERP's Bill of Materials model from *operations definition* model of this document or a reference to another object model in the document.
	Represents an IEC 62264 object as a UML class in UML diagram for an IEC 62264 object model to define an information model or set. Each object (UML class) has the same types of attributes. Each object is uniquely identifiable or enumerable by its name, attributes, and relationships within the object model. No UML operations or methods are listed for the objects (i.e., UML classes).
	Generalization: an element of the UML class is a specialized type of the super UML class. The arrow points to the super UML class.
	Association relationship: refer to 3.3.4.2.
	Association class: refer to 3.3.4.3.
	Dependence relationship: refer to 3.3.4.4.
	Aggregation relationship: refer to 3.3.4.5.
	Composition relationship: refer to 3.3.4.6.

NOTE 1 The relationships in the UML diagram provides a view into object life cycles at the time of an information exchange. The navigation shown in the UML diagram is the most commonly applied; however, some implementation methods and technologies can require a bidirectional relationship or can require the relationship roles for both ends of the relationship to be specified.

NOTE 2 Cardinality is used in multiple objects defining relation and association.

NOTE 3 The "has properties of" is a composition relationship where the composite relationship is only defined in the context of the information exchange lifecycle.

The defined relationship in the object model diagrams in combination with the model's relationship table and each object's relationship tables for each object define the "minimum" conformance requirements. Additional relationships and roles required for implementation are explicitly defined as noncompliant in the implementation documentation.

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3.3.4 Relationship types and name convention

3.3.4.1 General

This subclause explains the use, meaning, notation, and name conventions of the relationship types used in this document. Each relationship type that is graphically shown in the information models have their relationship semantics further defined using the combination of the relationship table for each information model and the relationship role table in each object's subclause in an information model clause.

IEC 62264 uses the following UML relationship types in the object model diagrams which are defined in 3.3.4.2, 3.3.4.3, 3.3.4.4, 3.3.4.5 and 3.3.4.6:

a) association,

b) association class,

c) dependency,

d) aggregation, and

e) composition.

3.3.4.2 Association

The association type represents a relationship between two objects (UML class) and their elements. An association has a relationship name, direction, relationship roles, and multiplicity. An association has role names at the end points that explain how each object participates in the relationship.

The UML symbol and notations for the association relationship in this document is shown in Table 1. A solid line symbol indicates an association between objects. For unidirectional relationships, the arrowhead symbol at the head end point represents the target role where the source role has no symbol on its tail end point. For a bi-directional relationship, no arrowhead symbol is used on the relationship end points where the source and target roles are defined by purpose of data exchange.

Each association relationship role has multiplicity for the expected number or range of each object member in the relationship. The notation, '*', indicates an indeterminate number of objects participate in the relationship.

EXAMPLE 1 The 0..* multiplicity means zero or more members of the subclass can exist.

The semantics for each object participating in the association relationship are defined in the information model's relationship table and each object's relationship role table. The relationship role names are not graphically specified in the IEC 62264 object model (UML diagram), but rather are defined in each object's relationship role table.

EXAMPLE 2 In Figure 15, the unidirectional association relationship between "1" *material definition* object as the target role defines "0..*" *material lot* objects as the source role; in contrast, "1" *material lot* object is defined in part by "1" *material definition* object. Per Table 90, the target role attribute, "material definition", is part of the definition of *material lot* while per Table 86, the source role attribute is part of the definition of *material definition*.

EXAMPLE 3 In comparing one data exchange implementation to another, the *material lot* objects associated with a *material definition* are recorded in the *material definition* database occurrence; but comparison to another implementation, the *material lot* objects are recorded in separate database systems using link table references.

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3.3.4.3 Association class

The association class type is an object (UML class) that is part of an association relationship between two other objects. An association class is

a) attached to an association relationship to provide additional information about the relationship;
b) used to capture certain characteristics of an association between two objects; and

NOTE These characteristics do not belong to the objects being associated but instead belong to the association relationship between the objects.

c) a type of defined association relationship with its own attributes, properties, and operations.

An association class relationship uses the symbol of a dashed line that connects an association line and association class object; as shown in Table 1, objects A and B are IEC 62264 objects whose association relationship is further defined by the association class object C. If A and B are the same objects, A and B are child objects in the association class relationship with no distinctions made between A and B objects. A and B have target roles in the association class relationship to allow distinction of them as child objects of object C as the parent with the source role.

EXAMPLE 1 A student (Object A) and a course (Object B) have an association class called enrolment (Object C), which has attributes such as grade and date.

EXAMPLE 2 Referring to Figure 17 and 5.8.12, the *segment dependency* is an association class object and with an association class relationship to further define how *process segments* execute with each other.

3.3.4.4 Dependency

The dependency type represents a relationship between two objects as a weak association where one object (UML class) depends on another for a defined purpose. A dependency has a relationship name, a direction, relationship roles, and a multiplicity. A dependency implies that a change in one object can affect the other depending on the purpose of the information exchange.

The UML symbol and notations for the dependency relationship in this document are shown in Table 1. The dashed line symbol indicates a weak association between objects. As unidirectional relationships, the arrowhead symbol at the head end point represents the target role from the source role with no symbol on its tail end point. Dependency relationships in IEC 62264 are unidirectional. Each object has a semantic link to the other object, which can be required to be satisfied before the object can be created. A dependency relationship designates that a single object or a set of objects require other objects in their specification or implementation.

The semantics for each object participating in the dependency relationship are defined in the information model's relationship table and each object's relationship role table. The relationship role names are not graphically specified in the IEC 62264 object model (UML diagram) but rather are defined in each object's relationship role table.

3.3.4.5 Aggregation

An aggregation type represents an object (UML class) in the context of a "whole" object made up of "members" objects (equivalent to a UML part class). The UML symbol and notations for the aggregation relationship in this document is shown in Table 1. A solid line symbol indicates an association between objects. The white diamond symbol at the tail end point graphically indicates the whole object while the object at the arrowhead symbol at the head endpoint indicates the member (part) object of the relationship.

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The aggregation relationship is qualified by the target and source roles of the relationship. An aggregation type in this document is defined with the following keywords:

a) whole: source object is the UML whole object in the aggregation;

b) member: target object is the UML part object in the aggregation; and

c) hierarchy: any object can be both a whole and member object in a recursive hierarchy.

EXAMPLE 1 The “is made up of” aggregation relationship on *equipment* object is a recursive hierarchy in Figure 12.

The aggregation notation identifies the member object as independent of the whole object in the lifecycle constraints of the information exchange and its purpose. The member object’s physical relationship is independent of its information exchange relationship and its exchange lifecycle. As shown in Figure 1, the member objects can be a part of multiple whole objects simultaneously. A1 aggregates B1, B2, and B3. A2 aggregates B3 and B4. When a whole object is deleted, the member objects are not deleted in terms of the lifecycle constraints of the information exchange and its purpose. A member object can be either completely represented in the whole object or referenced from the whole object.

NOTE This infers implementations can utilize whole and member prefixes or link tables if navigation of the hierarchy is required. In an aggregation hierarchy when a whole object is deleted, the relationships to other member objects are removed in link tables but the member objects are not deleted.

EXAMPLE 2

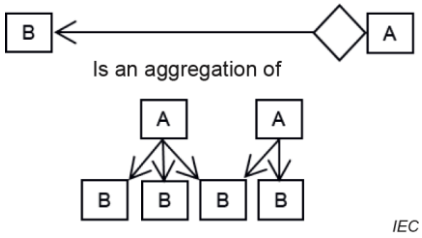


Figure 1 – Example of aggregation relationship notation

3.3.4.6 Composition

A Composition type represents an object (UML class) in the context of a “parent” object (UML “whole” class) containing child objects (UML “part” class). Composition type is a type of aggregation.

The composition relationship is qualified by the target and source roles of the relationship. A composition type in this document is defined with the following keywords:

a) parent: source object is the UML whole object in the composition;

b) child: target object is the UML part object in the composition; and

c) hierarchy: any object can be both a parent and child object in a recursive hierarchy.

EXAMPLE 1 The “contains” composition relationship on *material property* object is a recursive hierarchy in Figure 15

As shown in Figure 2, a composition relationship specifies that the lifetime of the child object is dependent on the lifetime of the parent object within the information exchange lifecycle. Composition shows a strong form of aggregation which requires

a) a child object instance as included in only one composition at a time and

b) the composition object has sole responsibility for disposition of its child objects.

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The UML symbol and notations for the composition relationship in this document are shown in Table 1. A solid line symbol indicates an association between objects. The black diamond symbol at the tail end point graphically indicates the parent object with a source role while the object at the arrowhead symbol at the head end point indicates the child object with a target role of the relationship.

NOTE A composition hierarchy can use parent and child prefixes or link tables if navigation of the hierarchy is required. If the root parent object is deleted, all child objects and their child objects are deleted. Objects can be both a whole and part object.

EXAMPLE 2

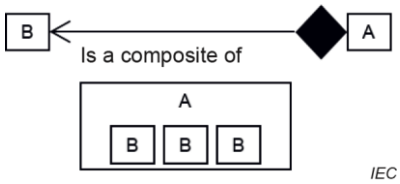


Figure 2 – Example of composition relationship notation

3.3.4.7 Relationship name convention

The relationship name convention identifies and describes the connection between the IEC 62264 objects (UML classes) in an object model (UML diagram).

The relationship name convention is:

a) a meaningful name reflecting the real-world purpose of the exchanged data in the context of manufacturing operations and business processes;

b) the relationship type conveys semantics of object lifetimes and navigation in the MOM domain;

c) applying the UML standard recommendation, the relationship name is either a single verb word or simple phrase using an active tense to describe the relationship nature and the relationship direction per the arrow symbol; and

d) the relationship name shall enforce the meaning of each relationship type's own notation.

EXAMPLE 1 Relationship name are: "contains", "maps to", "evaluated by", "made up of", or "depends on".

Graphically, the relationship name is written near the middle of the relationship line in the UML diagram and not too close to any of the ends.

IEC 62264 relationship names are shown in Table 2 with example of relationship role name template by relationship type.

IEC 62264 relationships require direction and multiplicity for the complete conceptual model required for design of logical and physical data models for implementation.

Inheritance is specified in class, definition, and type objects that are inherited in the properties of instance objects. Refer to Annex F.

NOTE IEC 62264 does not use the generalization relationship in the object models since an "is a" phrase is the UML standard recommendation for naming a generalization ISO/IEC 19501. The "is a" relationship name is used to describe the inheritance relationship between the generic objects (UML class) an subclass objects where a generalization is a relationship that indicates that one object is a specific kind of another object. Per the UML standard, a generalization does not have a direction or a multiplicity.

EXAMPLE 2 A generalization between Employee and Manager objects (UML class) is named "is a" (a manager is an employee). A generalization implies that the subclass inherits the features of the superclass.

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In a small number of cases due to updated naming conventions, the current IEC 62264 relationship names have changed from earlier versions of this document. Due to backward compatibility, these changed older relationship names can be in an adapted form where possible.

Implementations use this information in conjunction with 3.3.4 to determine the appropriate implementation model and object naming convention that is aligned in IEC 62264. Object lifetime and relationship navigation for a specific implementation is represented in the associated implementation documentation.

EXAMPLE 3 Manufacturing information exchange profile, template, or specification.

3.3.4.8 Relationship role name convention

The IEC 62264 relationship role name convention identifies how an object participates in the data exchange relationship within the MOM domain while considering the relationship type in the name (active tease verb). Logical and physical implementation models can use the following naming strategies when producing an implementation model.

EXAMPLE 1 Example of the derived implementation models from the conceptual object model are represented in Annex I conceptual model to logical data and physical models for implementation examples.

Graphically, the relationship role name in IEC 62264 is not shown for the object model in the UML diagram.

The relationship role name convention is:

a) the role name describes how each object (UML class) participates in the relationship when read in context of the relationship name;

b) each object shall hold a role reference to their associated objects using the source and target role names for relationship attributes as part of the object definition;

c) the source role and target role value for each object's relationships are defined in the relationship role table in the object's subclause as a logical name that can convey semantics of the related object in some implementations;

d) where logically appropriate, a role name uses the object name as the base noun to describe how an object participates in the relationship;

e) the role name syntax shall consist of

   1) the object name as the name prefix or first word in a short phase with a space followed by and

   2) a descriptive adjective as the name suffix or ending word (in a short phrase if required for role context);

   EXAMPLE 2 Object name = *Material lot*; Implementation name = MaterialLot

   IEC 62264 is a set of conceptual information models used to design logical and physical implementation models such as schema; Consequently, the relationship role is a required reference attribute with multiplicity in an object schema in an implementation. The best practice to use the associated objects' name to provides a clear description as opposed using a simple verb as a role name. Adjective name suffix is added when additional description is required such as in a parent/child hierarchy or a whole/member collection.

f) implementation names in logical and physical data model are typically represented without spaces and have the first letter of each word capitalized;

g) object type representation: The structure (type) of an object is represented by an object name without spaces and 'Type' suffix;

   EXAMPLE 3 Object name = *Material lot*; Object type = MaterialLotType.

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h) a contained object: The object's attribute name is the object name. The object type is the object name with 'Type' suffix;

EXAMPLE 4 Object name = *Material lot*; Object type = MaterialLotType.

i) a referenced object through a relationship (not contained physically in the object): Object name has an 'ID' appended to the object name. The object type is the object name with 'Type' suffix;

EXAMPLE 5 Object name = *Material lot ID*; Object type = MaterialLotIDType

j) a related object, single occurrence: The relationship-related object name is the name of the object. The object type is the object name with 'Type' suffix;

EXAMPLE 6 Object name = *Material lot*; Object type = MaterialLotType

k) a related object, multiple occurrences: Each occurrence is the object name when the message format allows (e.g., XML) or within a collection object with the object name as the plural of the object name;

EXAMPLE 7 Material lot is the attribute name for a collection of *material lot* entries.

NOTE *Equipment* is a special case for plurality in that the object name is used in both contexts, singular and plural. In many implementations, the representation of equipment is a hierarchy, which allows the use of parent *equipment* and child *equipment* as presented below.

l) a related recursive object, multiple occurrences with different semantic meaning: The relationship object name is used as prefix to distinguish the two entries; and

EXAMPLE 8 *Equipment* parent, *equipment* child.

m) in a composite object part, the multiplicity value is one: In an implementation that uses containment (the part is physically contained in the whole, not represented as a reference), the containment infers the multiplicity of one representation. The whole object is still represented as an attribute of the part in implementation models where navigation from part to whole explicitly is required.

EXAMPLE 9 *Equipment asset* mapping. *Equipment* is an *equipment asset* mapping type which contains the identifiers and other attributes defining the relationship between objects.

The relationship role name shall apply the role name template for each relationship name by type as shown in Table 2.

Table 2 – Relationship role name template with examples for each relationship name by relationship type

Relationship type	Relationship name	Role name template / Example
Association	Characterized by Use case: Supports association relationship between *resource actuals* and *test result* in the operations test model.	Source Role: (object name) Example 1a: Person actual Target Role: (object name) Example 1b: Test result
Association	Corresponds to Use case: Supports association relationship between an object to an object.	Source Role: (object name) Example 2a: Evaluated property Target Role: (object name) Example 2b: Tested property
Association	Derived from Use case: Supports association relationship between an object to an object.	Source Role: (object name) Example 2a: Operations segment Target Role: (object name) Example 2b: Process segment

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Relationship type	Relationship name	Role name template / Example
Association	Derived from (an object in) Use case: Cross-model relationship from object in information model to an object.in another information model.	Source Role: (object name) Example 3a: Equipment specification Target Role: (object name) Example 3b: Equipment class (equipment model)
Association	Created from Use case: Supports association relationship between *work directive* to *work master* in IEC 62264-4.	Source Role: (object name) Example 4a: Work directive Target Role: (object name) Example 4b: Work master
Association	Created from requirements Use case: Supports association relationship between *work directive* to *job order* in IEC 62264-4.	Source Role: (object name) Example 5a: Work directive Target Role: (object name) Example 5b: Job order
Association	Defined by Use case: Supports association relationship between the instance object to class object.	Source Role: (object name) Example 6a: Person Target Role: (object name) Example 6b: Personnel class
Association	Evaluated by Use case: Supports association relationship between *evaluated property* and *test specification property* in the operations test model.	Source Role: (object name) Example 7a: Evaluated property Target Role: (object name) Example 7b: Test specification property
Association	Generated in context of Use case: Supports association relationship between *test result* and an object for the *operations test requirement* in the operations test model.	Source Role: (object name) Example 8a: Test result Target Role: (object name) Example 8b: Personnel segment specification
Association	Has associated Use case: Supports association relationships in the operations definition model.	Source Role: (object name) Example 9a: Operations definition Target Role: (object name) Example 9b: Operations material bill
Association	Implemented by Use case: Supports association relationship from *equipment* to *physical asset* in the physical asset information model.	Source Role: (object name) Example 15a: Equipment Target Role: (object name) Example 15b: Physical asset
Association	Instance of Use case: Supports association relationships between *operations material bill item* and *material specification*.	Source Role: (object name) Example 15a: Operations material bill item Target Role: (object name) Example 15b: Material specification
Association	Includes properties of Use case: Supports association relationships between the derived class object as a specialization of the base class(es) by including their properties.	Source role: (object name) derived Example 10a: Personnel class derived Target role: (object name) base Example 10b: Personnel class base
Association	Measured with method of Use case: Supports association relationship between *Evaluated property* and *work definition* in the operations test model.	Source Role: (object name) Example 11a: Evaluated property Target Role: (object name) Example 11b: Work master

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Relationship type	Relationship name	Role name template / Example
Association	Member of Use case: Supports association relationship between a definition object as a member and a class object as the parent collection. Used in the material Information and operations event information models.	Source Role: (object name) member Example 12a: Material definition member Target Role: (object name) collection Example 12b: Material class collection
Association	Records and evaluates measurement of Use case: Supports association relationship between *property measurement* and *work definition* in the operations test model.	Source Role: (object name) Example 13a: Property measurement Target Role: (object name) Example 13b: Person property
Association	Records test results for Use case: Supports association relationship between *test result* and *testable object* in the operations test model.	Source Role: (object name) Example 14a: Test result Target Role: (object name) Example 14b: Personnel class
Association	Records use of Use case: Supports association relationship from *equipment asset mapping* to *equipment* and *physical asset* in the physical asset information model.	Source Role: (object name) Example 15a: Equipment asset mapping Target Role: (object name) Example 15b: Equipment
Association	Records value of Use case: Supports association relationship between *test result* and *testable object property* in the operations test model.	Source Role: (object name) Example 15a: Property measurement Target Role: (object name) Example 15b: Personnel class property
Association	Reported by Use case: Supports association relationship between *operations request* and *requested segment response* in the operations schedule model.	Source Role: (object name) Example 16a: Operations request Target Role: (object name) Example 16b: Requested segment response
Association	Specifies Use case: Supports association relationships from the *operations test requirement* or the *testable object* to the *test specification* in the operations test model.	Source Role: (object name) Example 17a: Personnel requirement Target Role: (object name) Example 17b: Test specification
Association	Specifies test for Use case: Supports association relationships from the *test specification* to the *operations test requirement* or the *testable object* in the operations test model.	Source Role: (object name) Example 18a: Test specification Target Role: (object name) Example 18b: Personnel requirement
Association class	Executes dependent on Use case: The association class object as the *segment dependency* has additional relationship attributes that define the relationship between the source and target objects for the *process segment* and *operations segment*.	Source Role: From (object name) Example 19a: From process segment Target Role: To (object name) Example 19b: To process segment

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Relationship type	Relationship name	Role name template / Example
Dependency	Maps to Use Case 1: In support of the definition type attribute, the “instance” or “child pattern” includes the objects, relationships, and properties of the associated “pattern (template)” for the following objects: *operations definition, operations segment, process segment, operations record specification, operations event class record specification, operations event record specification, work master* (IEC 62264-4), or *workflow specification* (IEC 62264-4).	Use case 1a: Instance mapped to pattern Source Role: (object name) instance Example 20a: Operations definition instance Target Role: (object name) pattern Example 20b: Operations definition pattern Use case 1b: Child pattern mapped to pattern Source Role: (object name) child pattern Example 21a: Operations definition child pattern Target Role: (object name) pattern Example 21b: Operations definition pattern
Dependency	Maps to Use Case 2: In support of the resource property object mapping to the resource class property.	Source Role: (object name) Example 22a: Equipment property Target Role: (object name) Example 22b: Equipment class property
Dependency	Maps to (a property object in) Use Case 3: In support of the cross-model relationship that maps a resource specification, requirement, or actual property to a resource class or instance property.	Source Role: (object name) Example 23a: Equipment requirement property Target Role: (object name) Example 23b: Equipment class property
Dependency	References Use case: Supports dependency relationship from a dependent object to a contributing object.	Source Role: (object name) Example 24a: Operations definition Target Role: (object name) Example 24b: Bill of material (external)
Dependency	Specified by Use case: Supports dependency relationship from a dependent *operations record template* to the *operations record specification* in the operations record model.	Source Role: (object name) Example 25a: Work record Target Role: (object name) Example 25b: Work record specification
Aggregation (hierarchy)	Assembled from Use case: Supports the recursive hierarchy relationship of a material-based object where the material member objects are parts of the assembly whole object. The material-based member objects in the material model are represented as the associated “assembly (abbreviated object name) whole objects.	Source Role: assembly (abbreviated object name) whole Example 26a: assembly lot whole Target Role: assembly (abbreviated object name) member Example 26b: assembly lot member
Aggregation (hierarchy)	Made up of Use case: Supports the recursive hierarchy relationship of an object where the member object(s) makes up part of the whole object.	Source Role: (object name) whole Example 27a: physical asset class whole Target Role: (object name) member Example 27b: physical asset class member
Aggregation	Made up of Use case: Supports the aggregation relationship of an object where the member object(s) makes up part of the whole object. This use case is applied from *work request* to the *job order* in work schedule model in IEC 62264.	Source Role: (object name) whole Example 27a: work request whole Target Role: (object name) member Example 27b: job order member

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Relationship type	Relationship name	Role name template / Example
Composition	Collection of Use case: Supports a composition relationship where an object is a collection of zero or one-to-many objects. Supports the following objects: IEC 62264-2: *test specification, operations event, operations schedule, operations performance, operations capability, process segment capability,* and *operations segment capability* IEC 62264-4: *work schedule, work performance, work master capability, and work capability*.	Source Role: (object name) Example 28a: Test specification Target Role: (object name) Example 28b: Test specification criteria
Composition	Contains Use case: Supports a composition relationship where a parent object contains zero or one-to-many child objects. Supports the following objects: IEC 62264-2: *process segment, operations schedule, operations performance, operations capability, process segment capability,* and *operations segment capability* IEC 62264-4: *work master, work directive, process workflow, work schedule, work performance, work master capability, and work capability*.	Source Role: (object name) Example 28a: process segment Target Role: (object name) Example 28b: personnel segment specification
Composition	Has record specification of Use case: Supports a composition relationship where the *operations event class* is specified by the *operations event class record specification* in the operations event model.	Source Role: (object name) Example 29a: Operations event class whole Target Role: (object name) Example 29b: Operations event class record specification
Composition	Has values of Use case: Supports a composition relationship where an object is defined in part by the values of the property object.	Source Role: (object name) Example 30a: Person Target Role: (object name) Example 30b: Person property
Composition	Has properties of Use case: Supports a composition relationship where an object has the values of one-to-many property objects.	Source Role: (object name) Example 31a: Personnel specification Target Role: (object name) Example 31b: Personnel specification property
Composition	Records action on Use case: Supports a composition relationship where an object record template records each action on each *operations record entry* in the operations event and work record models.	Source Role: (object name) Example 32a: Operations event record Target Role: (object name) Example 32b: Operations record entry
Composition hierarchy	Contains Use case: Supports a recursive composition hierarchy relationship where child object(s) are part of the parent object as the whole.	Source Role: (object name) parent Example 33a: Person property parent Target Role: (object name) child Example 33b: Person property child

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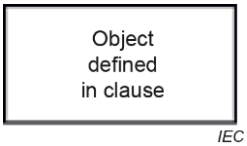
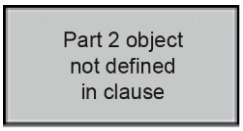
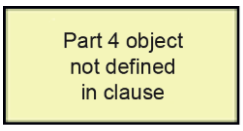
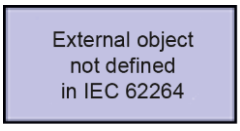
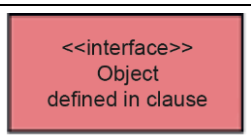
3.3.5 Object color convention

3.3.5 defines the object color convention used to define object relationships, The object color convention shown in Table 3 are used in object models' UML diagrams and related tables of this document and IEC 62264-4.

The objects specifically defined in each clause shall be designated by white background in the UML diagram and tables in the clause; the relationships to objects defined in another clause of this document's part shall be designated by gray background in the UML diagram and tables in the clause; and the relationships to objects defined in an IEC 62264-4 clause shall be designated by a beige background.

For the objects in each UML diagram that are not defined in the clause represented by the UML diagram, their basic relationships to objects defined in the clause are shown to illustrate the complete context of information model of the defined objects.

Table 3 – Object color convention

Object type	Color convention
	Object defined in clause: White background in an IEC 62264 object (UML class symbol) and in a cell of the clause's relationship role table indicates the object is specifically defined in the clause defining the object model.
	Part 2 Object not defined in clause: Gray background in an IEC 62264 object (UML class symbol) and in a cell of the clause's relationship role table indicates the object is not defined in the clause defining the object model but is defined in another clause and object model of IEC 62264-2.
	Part 4 Object not defined in clause: Beige background in an IEC 62264 object (UML class symbol) and in a cell of the clause's relationship role table indicates the object is not defined in any clauses of IEC 62264-2 but is defined in an IEC 62264-4 clause and object model.
	External Object not defined in IEC 62264: Light blue background of an IEC 62264 object (UML class symbol) and in a cell of the clause's relationship role table indicates the object is not defined in any clauses of IEC 62264 and shall be defined in an external document.
	<<interface>> Object defined in clause: Pink background of an IEC 62264 object (UML class symbol) and in a cell of the clause's relationship role table indicates the object is defined as an interface abstract object in IEC 62264-2.

3.3.6 Relationship table

The relationships in each object model's UML diagram are explicitly defined by the simplified UML model in combination with a relationship table. The relationship table lists each relationship for each object in the object model.

The object model's relationship tables indicate an object name for both end points, the type of relationship, and the relationship name for each relationship between objects in an information model. The object's relationship table uses the following UML object's relationship types to identify the relationship between objects. In the object's relationship table, the object's relationship is defined specifically from each object's perspective.

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EXAMPLE 1 The UML diagram of personnel model in Figure 3 below in combination with the associated relationship table in Table 4 shows the *personnel class* object's relationships as an example of how the standard represents each object's relationships in the context of the information model.

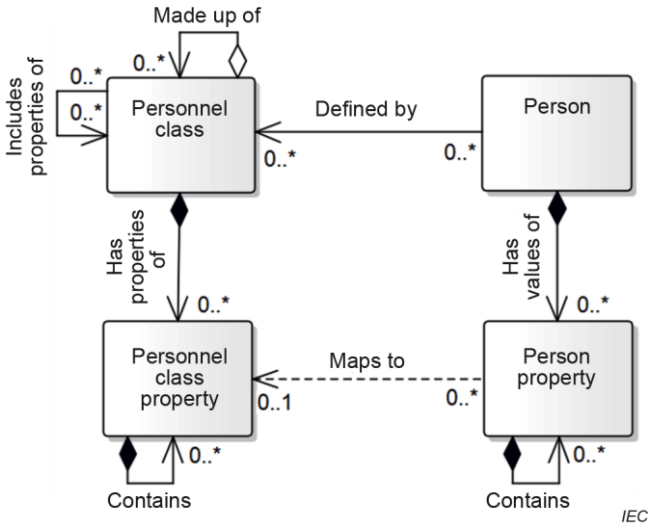


Figure 3 – Example: Object model using the simplified UML diagram for an information model, personnel model

The column headers for the object relationship table are:

a) source object: represents the source of the relationship direction;

b) target object: represents the destination of the relationship direction;

c) relationship type: represents the relationship type as defined; and

d) relationship name: is the name given to the relationship type and provides a description of the type or direction of the relationship.

Table 4 – Example: Relationship table for an object model, personnel model relationships

Source object	Target object	Relationship type	Relationship name
Personnel class	*Personnel class property*	Composition	Has properties of
Personnel class	*Personnel class*	Association	Includes properties of
Personnel class property	*Personnel class property*	Composition hierarchy	Contains
Person	*Personnel class*	Association	Defined by
Person	*Person property*	Composition	Has values of
Person property	*Personnel class property*	Dependency	Maps to
Person property	*Person property*	Composition hierarchy	Contains
Personnel class	*Test specification*	Association	Specifies
Person	*Test specification*	Association	Specifies
Test specification	*Personnel class*	Association	Specifies test for
Test specification	*Person*	Association	Specifies test for
Test result	*Personnel class*	Association	Records test results for
Test result	*Person*	Association	Records test results for
Evaluated property	*Personnel class property*	Association	Corresponds to
Evaluated property	*Person property*	Association	Corresponds to
Property measurement	*Personnel class property*	Association	Records measurement of
Property measurement	*Person property*	Association	Records measurement of

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3.3.7 Relationship role table

Relationship roles are used to explicitly define relationships between objects in an information model by listing the roles of related objects to the object being defined in the relationship role table. A role name explains how an object participates in the relationship. Each related object holds a reference to the associated object or objects.

NOTE 1 In an implementation, the reference is held in an attribute value within the object. When there is only one association then there is only one attribute holding a reference.

The relationship role table provides the roles related to the object's source-to-target relationship which establish the expected rules and the purpose for an implementation to provide additional details for the object in combination with the attribute tables.

NOTE 2 Some implementations can require the definition of bi-directional relationships and roles which are listed in the relationship role tables.

The column headers for the object relationship role table are

a) related object: for the given source object, the object name related to the object defined in the clause through the specific relationship where the related object and defined object are ends point in the relationship with defined roles;

b) roles: the source and target role names of the roles of related object and defined object in the context of their type of relationship;

c) multiplicity: multiplicity indicates cardinality of the related role of the source and target object; Multiplicity = Cardinality + Participation. Cardinality denotes the maximum number of possible relationship occurrences in which a certain object can participate (in simple terms: at most). Participation denotes if all or only some object occurrences participate in a relationship (in simple terms: at least);

   NOTE 3 A multiplicity can have the expected number or range of roles, when '*' indicates an indeterminate number. 0..* means that zero or more roles participate in the relationship.

   The multiplicity element defines some collection of objects and includes both multiplicity as well as specification of order and uniqueness of the collection elements;

d) relationship name: the name given to the relationship type and provides a description of the type or direction of the relationship; and

e) description: the description of the relationship from the viewpoint of the related object's role and/or description of the related object's role in the relationship.

EXAMPLE 1 The relationship role table example for the *personnel class* object in the example of the UML diagram of personnel model is shown in Table 5.

Table 5 – Example: Relationship role table, Personnel class relationship roles

Related object	Roles	Multiplicity	Relationship name	Description
Personnel class	Source role: personnel class derived Target role: personnel class base	0..* 0..*	Includes properties of	The derived *personnel class* is a specialization of the base *personnel class(es)* by including their properties.
Personnel class property	Source role: personnel class Target role: personnel class property	1 0..*	Has properties of	The *personnel class property* has the values in part of this *personnel class*.
Person	Source: person Target role: personnel class	0..* 0..*	Defined by	The *person* is defined in part by this *personnel class.* The *person* objects support the *personnel class property(ies)* associated with this *personnel class*.

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3.3.8 Object attribute table

An object attribute table of a given object lists and defines the attributes of the object. The object attribute table includes object identification, references to resources, object relationships, related object naming convention, and object relationship implementations.

Attributes in the tables are considered optional, except where specified as required in the attribute description.

The column headers for the object attribute table are:

a) attribute name: Each attribute is specified with its attribute name;

b) description: Description of attribute;

c) examples: Examples of attribute value for each of the four main operation management categories (i.e., production, maintenance, quality, and inventory operations) defined in IEC 62264-1 in the object attribute table. Table 6 shows how the attribute example rows and columns are used.

Table 6 – Example: Usage of object attribute table

Attribute name	Description	Production example	Maintenance example	Quality example	Inventory examples
Name of first attribute	Description of first attribute	Production example	Maintenance example	Quality example	Inventory example
Name of second attribute	Description of second attribute	Production example	Maintenance example	Quality example	Inventory example
Name of third attribute	Description of third attribute	Production example	Maintenance example	Quality example	Inventory example

When an example value is a set of values, or a member of a set of values, the set of values is given within a set of braces, {}.

The examples are purely fictional. They are provided to further describe attributes in the model. It is not intended to make the examples complete or representative of any manufacturing enterprise.

NOTE 1 Within a table the columns for production, maintenance, quality, and inventory can be examples where the four operations management categories are coordinated, or they can be separate examples.

EXAMPLE 1 When one system is coordinating multiple operations management categories, the IDs used in each column can be the same. When different systems coordinate multiple operations management categories, the IDs can be different.

Example values of an attribute are meant to be illustrative and do not imply requirements.

NOTE 2 Time and date attributes can illustrate a general or specific time horizon.

EXAMPLE 2 A yearly or quarterly plan can use general dates with no specific time, while a detailed schedule can include a specific datetime value down to the minute.

EXAMPLE 3 Data resolution used in the examples are typical examples.

Specific implementations of this part can specify the data resolution required for each attribute.

When “(Not applicable)” is used as an attribute example, it is only illustrative that there is not a value for this attribute in the example. It does not imply there can never be a value. This is also true when all four example columns contain (Not applicable).

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3.3.9 Relationships between resource reference objects in operations management information models and resource models

The operations management information models in this document use a simplified method to graphically represent the relationships between resource reference objects and the relationships to their supporting resource information models. In order to make the UML diagrams for the object models less complex, the simplified UML model does not fully document the following:

a) the cross-model relationships between a specific *resource reference object* (resource specification, requirement, actual, and capability) in an information model to an associated object(s) in the resource information model;

b) the cross-model relationships between *resource reference objects* in different information models (i.e. resource requirement to specification or resource actual to requirement).

The simplified UML models are not fully conformant to the UML notational methodology as defined in ISO/IEC 19501. The simplified UML techniques in this document are intended as a visualization method for use in combination of the object attribute tables, object model's relationship table, and each object's role tables to provide a complete explicit definition for the conceptual information exchanges to support compliant integration implementations.

The simplified UML model in Figure 4 is applied to the cross-model relationships between objects in the operations management information models shown in Figure 6. Figure 6 provides an informative illustration of how the conceptual information models for operations management interrelate using relationships between the objects in different object models.

Figure 4 illustrates resource model referencing method in the simplified UML model in this document in the left column to compare the detailed relationships per the ISO/IEC 19501 compliant UML model in the right column.

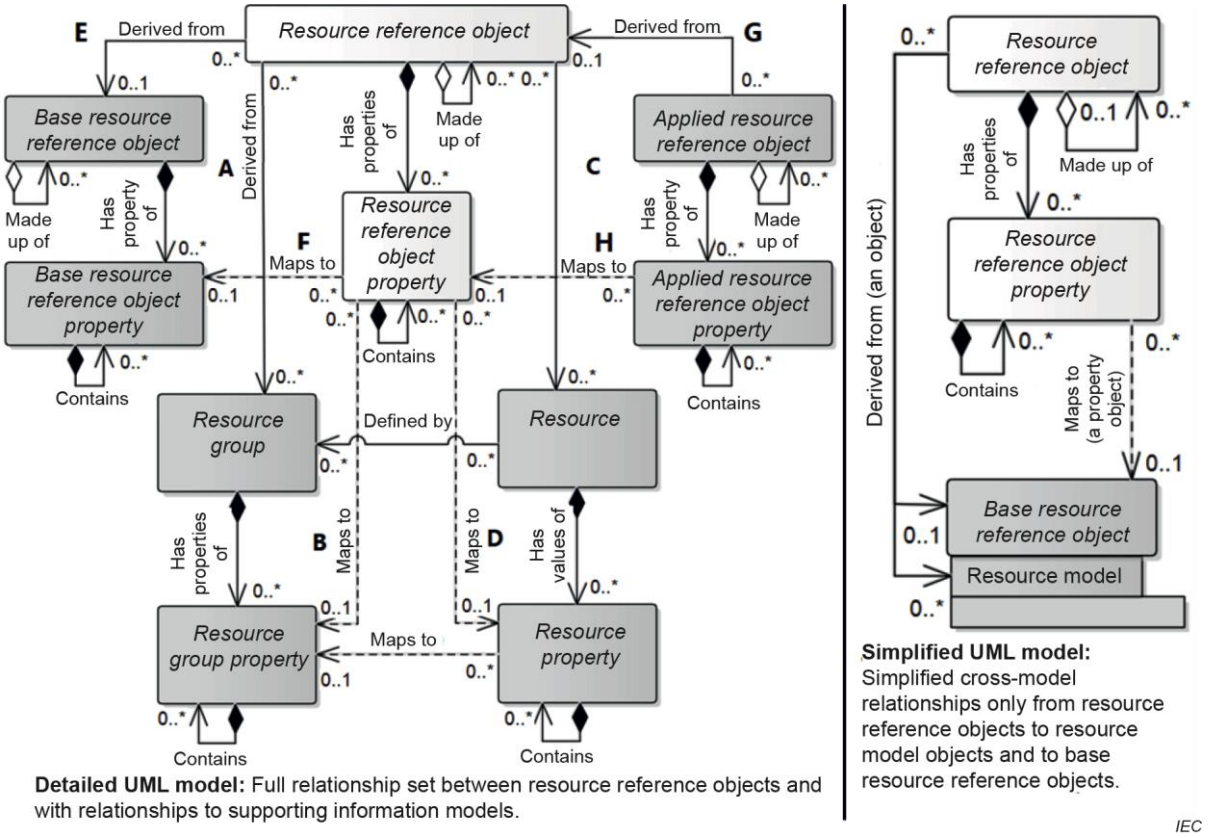


Figure 4 – Simplified UML model convention for cross-model relationships between resource objects

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NOTE 1 Simplified UML model does not show the *applied resource reference object*, the *applied resource reference object property*, and their relationships; these objects and relationships from detailed UML model are defined in each information model relationship table and associated object relationship role table.

The "Maps to (a property object)" relationship in simplified UML model from the resource refence object property can reference either a base resource reference object property or a resource model property (grouping or instance).

In simplified UML model, the "derived from" relationship to the resource model can correspond to either the resource group or resource object.

The implemented association relationship of the detailed UML model for a *resource reference object* and its *resource reference object property* are defined through a subset of the following four relationships or paired relationships shown in Figure 4:

a) A,
b) A and B,
c) C,
d) C and D
e) E,
f) E and F,
g) G,
h) G and H.

The abstract, reference terms for resource objects in Figure 4 are:

a) *resource reference object, base resource reference object*, and *the applied resource reference object*: Table 7 details the available relationships between each of these objects**;**
b) *resource group*: *personnel class*, *equipment class*, *physical asset class*, *material class*, and *material definition* objects;
c) *resource*: *person, equipment, physical asset, material lot, and material sublot objects.*

NOTE 2 For implementation explanation, refer to Clause E.8 and Clause E.14.

Table 30 in 4.3 lists the operations management information models that apply the simplified resource and resource reference information models in Figure 6. Table 30 contains resource objects and defines the set of possible relationships to each specific resource group, resource instance object, base resource reference object, and applied resource reference object within each model.

Table 7 lists the cross-model object relationships in the detailed UML model example in Figure 4.

Table 7 – Detailed UML model relationships in Figure 4

Source object	Target object	Relationship type	Relationship name
Resource reference object	*Resource group*	Association (A)	Derived from
Resource reference object	*Resource*	Association (C)	Derived from
Resource reference object property	*Resource group property*	Dependency (B)	Maps to
Resource reference object property	*Resource property*	Dependency (D)	Maps to
Resource reference object	*Base resource reference object*	Association (E)	Derived from
Resource reference object property	*Base resource reference object property*	Dependency (F)	Maps to

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Source object	Target object	Relationship type	Relationship name
Applied resource reference object	*Resource reference object*	Association (G)	Derived from
Applied resource reference object property	*Resource reference object property*	Dependency (H)	Maps to
Resource reference object	*Resource reference object property*	Composition	Has properties of
Resource	*Resource group*	Association	Defined by`
Resource	*Resource property*	Composition	Has values of
Resource group	*Resource group property*	Composition	Has properties of
Resource property	*Resource group property*	Dependency	Maps to
Resource property	*Resource property*	Composition hierarchy	Contains
Resource group property	*Resource group property*	Composition hierarchy	Contains

The following conventions apply for the relationship between the *resource reference object* and the resource model objects:

a) only one *resource* instance shall be allowed for a given *resource reference object* instance;

b) one *resource group* can be referenced; however, the *resource* instance can belong to many *resource groups* so the *resource reference object* can reference only the *resource groups* that apply to the business use of the *resource reference object*;

c) the paired relationships, Label A with B and Label C with D, show that a *resource reference object property* can be represented by a single dependency relationship to either a *resource class property* (B) or to a *resource property* (D) since the properties are in a composition relationship; and

d) the *resource reference object property* only shall reference a resource model property if the property's parent object has an association relationship (A or D) with the *resource reference object*.

The following conventions apply for the relationship between the *resource reference object* and the *base resource reference object* and their paired property objects:

a) only one instance of a *base resource reference object* is allowed for a given *resource reference object* instance;

b) a given *resource reference object* instance can have additional *resource reference object properties* that do not map to a given *base resource reference object property*;

c) the paired relationship, Label E with F, show that a *resource reference object property* can be represented by a single dependency relationship to a base *resource reference object property* (F) since the properties are in a composition relationship;

d) the *resource reference object property* only references a *base resource reference property* if the property's parent object has an association relationship (E) with the *resource reference object*.

The following conventions apply for the relationship between the *resource reference object* and the *applied resource reference object* and their paired property objects:

a) only one instance of a resource reference object is allowed for each applied resource reference object instance;

b) each *applied resource reference object property* instance shall map to a specific *resource reference object property*;

c) the paired relationship, Label G with H, show that an *applied resource reference object property* can be represented by a single dependency relationship to a *resource reference object property* (H) since the properties are in a composition relationship;

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d) the *applied resource reference object property* only references a *resource reference object property* if the property's parent object has an association relationship (G) with the *resource reference object*.

Table 30 lists the operations management information models of this part that apply the simplified resource reference model to:

a) reference the resource models to define the set of possible relationships to the specific *resource group* and *resource object*s within each model; and

b) reference the *resource reference objects* in the operations management models to define the set of possible relationships within each model to the specific *base resource reference object* and from the *applied resource reference object*.

Table 8 to Table 29 provide the relationship role table for the detailed UML model in Figure 4 with an example relationship role table for the following reference objects: *resource reference object, resource reference object property, resource group, resource group property, resource, resource property, base resource reference object, base resource reference object property, applied resource reference object, and applied resource reference object property*.

EXAMPLE 1 The following examples in Table 9 and Table 10 are extracted from relationship role table, Table 206, to illustrate the cross-model relationships between the *personnel requirement* (as the *resource reference object* in Table 8) and

a) *resource group* (A) and *resource* (C) and

b) *base resource reference object* (E) and *applied resource reference object* (G).

The *personnel requirement* relationships are shown in Figure 24.

Table 8 – Resource reference object relationship roles

Related object (Figure 4 relationship label: A, C, E, G)	Roles	Multiplicity	Relationship name	Description
Resource group (A)	Source role: resource reference object Target role: Resource group	0..* 0..*	Derived from	This *resource reference object* defined in part by *resource group(s)*. The *resource group(s)* support the *resource reference object property(s)* associated with this *resource reference object*.
Resource (C)	Source role: resource reference object Target role: resource	0..* 0..*	Derived from	This *resource reference object* defined in part by *resource(s)*. The *resource(s)* support the *resource reference object property(s)* associated with this *resource reference object.*
Base resource reference object (E)	Source role: resource reference object Target role: base resource reference object	0..* 0..*	Derived from	This *resource reference object* is defined in part by *base resource reference object.* *Base resource reference object* applies the *resource reference object property(s)* associated with this *resource reference object*.
Applied resource reference object (G)	Source role: applied resource reference object Target role: resource reference object	0..* 0..*	Derived from	This *resource reference object* is defined in part by *resource(s)*. The *resource(s)* support the *resource reference object property(s)* associated with this *resource reference object.*

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Related object (Figure 4 relationship label: A, C, E, G)	Roles	Multiplicity	Relationship name	Description
Resource reference object property	Source role: resource reference object Target role: resource reference object property	1 0..*	Has properties of	The *resource reference object property(s)* defines in part this *resource reference object*.

Table 9 – Example: Personnel requirement cross-model relationships to the personnel model (resource group and resource)

Related object	Roles	Multiplicity	Relationship name	Description
Personnel class (A)	Source role: personnel requirement Target role: personnel class	0.. * 0..*	Derived from	This *personnel requirement* is defined in part by *personnel class(s)*. The *personnel class property(ies)* support the *personnel requirement property(ies)* associated with this *personnel requirement*.
Person (C)	Source role: personnel requirement Target role: person	0..* 0..*	Derived from	This *personnel requirement* is defined in part by *person(s)*. The *person property(ies)* support the *personnel requirement property(ies)* associated with this *personnel requirement*.

Table 10 – Example: Personnel requirement cross-model relationships to the personnel reference objects

Related object	Roles	Multiplicity	Relationship name	Description
Personnel segment specification (E)	Source role: personnel requirement Target role: personnel segment specification	0.. * 0..*	Derived from	This *personnel requirement* is defined in part by *personnel segment specification*. The *personnel segment specification* property(ies) belongs to the *personnel requirement property(ies)* associated with this *personnel requirement*.
Personnel specification (E)	Source role: personnel requirement Target role: personnel specification	0.. * 0..*	Derived from	This *personnel requirement* is defined in part by *personnel specification*. The *personnel specification property(ies)* belongs to the *personnel requirement property(ies)* associated with this *personnel requirement*.
Personnel actual (G)	Source role: personnel actual Target role: personnel requirement	0..* 0..*	Produced to	This *personnel actual* is defined in part by *personnel requirement*. The *personnel requirement property(ies)* belongs to the *personnel actual property(ies)* associated with this *personnel actual*.

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EXAMPLE 2 The following examples are extracted from the relationship role table, Table 208, to illustrate the cross-model relationships between the *personnel requirement property* (as the *resource reference object property* in Table 11) and

a) *resource group property* (B) and *resource property* (D) in Table 12 and

b) *base resource reference object* property (F) and *applied resource reference object* property (H) in Table 13.

The *personnel requirement* relationships are shown in Figure 24.

Table 11 – Resource reference object property relationship roles

Related object (Figure 4 relationship label: B, D, F, H)	Roles	Multiplicity	Relationship name	Description
Resource group property (B)	Source role: resource reference object property Target role: resource group property	0..* 0..1	Maps to	This *resource reference object property* is defined in part by the *resource group property*.
Resource property (D)	Source role: resource reference object property Target role: resource property	0..* 0..1	Maps to	This *resource reference object property* is defined in part by *the resource property*.
Base resource reference property (F)	Source role: resource reference object property Target role: base resource reference object property	0..* 0..1	Maps to	This *resource reference object property* is defined in part by the *base resource reference property*.
Applied resource reference property (H)	Source role: applied resource reference object property Target role: resource reference object property	0..* 0..1	Maps to	This applied *resource reference object property* is defined in part by the *resource reference property*.
Resource reference object	Source role: resource reference object Target role: resource reference object property	1 0..*	Has properties of	This *resource reference object is* defined in part by the *resource reference object property(ies)*.

Table 12 – Example: Personnel requirement property cross-model relationships to the personnel model

Related object	Roles	Multiplicity	Relationship name	Description
Personnel class property (B)	Source role: personnel requirement property Target role: personnel class property	0..* 0..1	Maps to	This *personnel requirement property* is defined in part by *personnel class* property. The *personnel class property*(s) support *the personnel requirement property*(s) associated with this *personnel requirement*.
Person property (D)	Source role: personnel requirement property Target role: person property	0..* 0..1	Maps to	This *personnel requirement property* is defined in part by *person* property. The *person property*(s) support *the personnel requirement property*(s) associated with this *personnel requirement*.

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Table 13 – Example: Personnel requirement property cross-model relationships to the personnel reference object properties

Related object	Roles	Multiplicity	Relationship name	Description
Personnel segment specification property (F)	Source role: personnel requirement property Target role: personnel segment specification property	0..* 0..1	Maps to	This *personnel requirement property* is defined in part by *personnel segment specification property.* The *personnel segment specification property* belongs to *the personnel requirement property*(s) associated with this *personnel requirement*.
Personnel specification property (F)	Source role: personnel requirement property Target role: personnel specification property	0..* 0..1	Maps to	This *personnel requirement property* is defined in part by *personnel specification property*. The *personnel specification property* belongs to *the personnel requirement property*(s) associated with this *personnel requirement*.
Person actual property (H)	Source role: person actual property Target role: personnel requirement property	0..* 0..1	Maps to	This *person actual* Is defined in part by person requirement property. The *person requirement property*(s) support the *person actual property*(s) associated with this *person actual*.

EXAMPLE 3 The following example in Table 15 is extracted from the relationship role table, Table 208, to illustrate the cross-model relationship between the *personnel class* (as the *resource group* in Table 14) and *resource reference object* (A). The *personnel requirement relationships* are shown in Figure 24.

Table 14 – Resource group relationship roles

Related object (Figure 4 relationship label: A)	Roles	Multiplicity	Relationship name	Description
Resource reference object (A)	Source role: resource reference object Target role: resource group	0..* 0..*	Derived from	The *resource reference object* related to this *resource group*.
Resource group property	Source role: resource group Target role: resource group property	1 0..*	Has properties of	The *resource group property*(s) is a value of this *resource group*.
Resource	Source role: resource Target role: resource group	0..* 0..*	Defined by	The *resource* defined in part by this *resource group*.

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Table 15 – Example: Personnel requirement cross-model relationships to the personnel class

Related object	Roles	Multiplicity	Relationship name	Description
Personnel requirement (A)	Source role: personnel requirement Target role: personnel class	0..* 0..*	Derived from	The *personnel class(s)* defines in part this *personnel requirement*. The *personnel class property(s)* support the *personnel requirement property(s)* associated with this *personnel requirement*.

EXAMPLE 4 The following example in Table 17 is extracted from the relationship role table, Table 208, to illustrate the cross-model relationship of *personnel class property* (as the *resource group property* in Table 16) and *resource reference object property* (B). The *personnel requirement property* relationships are shown in Figure 24.

Table 16 – Resource group property relationship roles

Related object (Figure 4 relationship label: B)	Roles	Multiplicity	Relationship name	Description
Resource reference object property (B)	Source role: resource reference object property Target role: resource group property	0..* 0..1	Maps to	The *resource reference object property* is defined in part by this *resource group property*.
Resource group	Source role: resource group Target role: resource group property	1 0..*	Has properties of	The *resource group* is defined in part by a value of this *resource property*.
Resource group property	Source role: resource group property parent Target role: resource group property child	1 0..*	Contains	The child *resource group property(s)* of this parent *resource group property.*
Resource property	Source role: resource group property Target role: resource property	0..1 0..*	Maps to	The *resource property* is defined in part by this *resource group property*.

Table 17 – Example: Personnel requirement property cross-model relationships with the personnel class property

Related object	Roles	Multiplicity	Relationship name	Description
Personnel requirement property (B)	Source role: personnel requirement property Target role: personnel class property	0..* 0..1	Maps to	The *personnel class(s)* defines in part the *personnel requirement*. This *personnel class property(s)* belongs to the *personnel requirement property(s)* associated with the *personnel requirement*.

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EXAMPLE 5 The following example in Table 19 is extracted from the relationship role table, Table 208, to illustrate the cross-model relationship between a *person* (as the *resource* in Table 18) and the *resource reference object* (C). The *personnel requirement* relationships are shown in Figure 24.

Table 18 – Resource relationship roles

Related object (Figure 4 relationship label: C)	Roles	Multiplicity	Relationship name	Description
Resource reference object (C)	Source role: resource reference object Target role: resource	0..* 0..*	Derived from	This *resource* related to the *resource reference object*.
Resource group	Source role: resource Target role: resource group	0..* 0..*	Defined by	This *resource* defined in part by the *resource group*.
Resource property	Source role: resource Target role: resource property	1 0..*	Has values of	The *resource property(s)* has the value(s) in part of this *resource*.

Table 19 – Example: Personnel requirement cross-model relationships to the person

Related object	Roles	Multiplicity	Relationship name	Description
Personnel requirement (C)	Source role: personnel requirement Target role: person	0..* 0..*	Derived from	This *person(s)* belongs to the *personnel requirement*. This *person property(s)* belongs to the *personnel requirement property(s)* associated with the *personnel requirement*.

EXAMPLE 6 The following example in Table 21 is extracted from the relationship role table, Table 208, to illustrate the cross-model relationship between the *person property* (as the *resource property* in Table 20) and the *resource reference object property (*D). The *personnel requirement property* relationships are shown in Figure 24.

Table 20 – Resource property relationship roles

Related object (Figure 4 relationship label: D)	Roles	Multiplicity	Relationship name	Description
Resource reference object property (D)	Source role: resource reference object property Target role: resource property	0..1 0..*	Maps to	The *resource reference object property* related to this *resource group property*.
Resource	Source role: resource Target role: resource property	1 0..*	Has values of	The *resource* contains the values in part of this *resource property(s)*.
Resource group property	Source role: resource property Target role: resource group property	0..* 0..1	Maps to	This *resource property* defined in part by the *resource group property*.

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Table 21 – Example: Personnel requirement property cross-model relationships with the person property

Related object	Roles	Multiplicity	Relationship name	Description
Personnel requirement property (D)	Source role: personnel requirement property Target role: person property	0..* 0..1	Maps to	This *person(s)* defined in part by the *personnel requirement*. This *person property(s)* defined in part by the *personnel requirement property(s)* associated with the *personnel requirement*.

EXAMPLE 7 The following example in Table 23 is extracted from the relationship role table, Table 208, to illustrate the cross-model relationship between the *personnel specification* (as the *base resource reference object* in Table 22) and *resource reference object* (E). The *personnel requirement* relationships are shown in Figure 24.

Table 22 – Base resource reference object relationship roles

Related object (Figure 4 relationship label: E)	Roles	Multiplicity	Relationship name	Description
Resource reference object (E)	Source role: resource reference object Target role: base resource reference object	0..* 0…1	Derived from	This *base resource reference object* related to the *resource reference object*.

Table 23 – Example: Personnel requirement cross-model relationships to the personnel specification

Related object	Roles	Multiplicity	Relationship name	Description
Personnel requirement (E)	Source role: personnel requirement Target role: personnel specification	0..* 0..1	Derived from	This *personnel specification(s)* belongs to the *personnel requirement*. This *personnel specification property(s)* belongs to the *personnel requirement property(s)* associated with the *personnel requirement*.

EXAMPLE 8 The following example in Table 25 is extracted from the relationship role table, Table 208, to illustrate the cross-model relationship between the *personnel specification property* (as *base resource reference object property* in Table 24) and the *resource reference object property* (F). The *personnel requirement property* relationships are shown in Figure 24.

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Table 24 – Base resource reference object property relationship roles

Related object (Figure 4 relationship label: F)	Roles	Multiplicity	Relationship name	Description
Resource reference object property (F)	Source role: resource reference object property Target role: base resource reference object property	0..* 0..1	Maps to	The *resource reference object property* is related to this *base resource reference object property*.
Base resource reference object property	Source role: base resource reference object Target role: base resource reference object property	1 0..*	Has property of	The *base resource reference property(s)* contains the values of this *base resource reference object property*.

Table 25 – Example: Personnel requirement property cross-model relationships to the personnel specification property

Related object	Roles	Multiplicity	Relationship name	Description
Personnel requirement property (F)	Source role: personnel requirement property Target role: personnel specification property	0..* 0..1	Maps to	This *personnel specification propert*y is defined in part by the *personnel requirement property*. This *personnel specification property(s)* is defined in part by the *personnel requirement property(s)* associated with the *personnel requirement*.

EXAMPLE 9 The following example in Table 27 is extracted from the relationship role table, Table 208, to illustrate the cross-model relationship between the *personnel actual* (as the *applied resource reference object* in Table 26) and the *resource reference object* G). The *personnel requirement* relationships are shown in Figure 24.

Table 26 – Applied resource reference object relationship roles

Related object (Figure 4 relationship label: G)	Roles	Multiplicity	Relationship name	Description
Resource reference object (G)	Source role: applied resource reference object Target role: resource reference object	0..* 0...1	Derived from	This *applied resource reference object* is derived from the *resource reference object*.
NOTE Use “Produced to” relationship for resource actual to resource requirement.				

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Table 27 – Example: Personnel actual cross-model relationships to the personnel requirement

Related object	Roles	Multiplicity	Relationship name	Description
Personnel requirement (G)	Source role: personnel actual Target role: personnel requirement	0..* 0..1	Derived from	This *personnel requirement(s)* belongs to the *personnel actual*. This *personnel requirement property(s)* belongs to the *personnel actual property(s)* associated with the *personnel actual*.

EXAMPLE 10 The following example in Table 29 is extracted from the relationship role table, Table 208, to illustrate the cross-model relationship between the *personnel actual property* (as the *applied resource reference object property* in Table 28) and the *resource reference object property* (H). The *personnel requirement property* relationships are shown in Figure 24.

Table 28 – Applied resource reference object property relationship roles

Related object (Figure 4 relationship label: H)	Roles	Multiplicity	Relationship name	Description
Resource reference object property (H)	Source role: applied resource reference object property Target role: resource reference object property	0..* 0..1	Maps to	The *applied resource reference object property* is related to this *resource reference object property*.
Applied resource reference object property	Source role: base resource reference object Target role: base resource reference object property	1 0..*	Has property of	The *applied resource reference property(s)* contains the values of this *resource reference object property*.

Table 29 – Example: Personnel actual property cross-model relationships to the personnel requirement property

Related object	Roles	Multiplicity	Relationship name	Description
Personnel requirement property (H)	Source role: personnel actual property Target role: personnel requirement property	0..* 0..1	Maps to	This *personnel requirement property* defines the *personnel actual property*. This *personnel specification property(s)* defines in part the *personnel requirement property(s)* associated with the *personnel requirement*.

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