Quantity Takeoff using IFC R2.0

DRAFT 1 – 06.11.1999

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Introduction

Automating Quantity Takeoff is one of the most promising features the IFC model has to offer. In this paper I try to analyse what can already be done in this area and present some ideas how it could be done. As always, we should also consider what could be done better in future IFC releases.

I approach the question of quantity takeoff using 3 independent factors

1. How much
2. … of what
3. … where?

The culture of quantity takeoff and specially cost estimating varies considerably in different countries and regions. However, these basics should remain the same, as they are something everybody needs to know.

One further question that spans all of the factors mentioned above is the accuracy and granularity of the data.

Maybe the most difficult question in quantity takeoff is the question of responsibility. In different cultures different ‘players’ in the construction industry take responsibility for the quantities. This diversity makes it difficult to assess what kind of raw data the quantity takeoff programs will receive. If the provider of the raw data does not take any responsibility for the quantities the quantity takeoff process cannot be automated, even if the syntax and content of the data would allow this. Changing cultures is one of the most difficult things to do, and for a long time we will have to find workarounds to the existing

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problems. This will make it very difficult, if not impossible, to find a common universal way to deal with quantity takeoff in the IFC model in the near future.

But do not despair. Understanding how, and to what level, the IFC model can support quantity takeoff will make it easier for you to find the best way to apply it in your own construction culture.

What?

The 'what' part identifies the data (objects) that are exchanged between different programs.

There are several ways in the IFC model to identify what exactly an object is:

- The name of the class (e.g. IfcDoor)
  The basic identification of the object type.
- Pre defined types (e.g. DoorPanelSwinging)
  Identifies the more specific type of the object. The possible values are defined in the IFC model.
- User defined types
  Identifies the more specific type of the object. The values have to be agreed between implementers.
- Labels and other descriptive strings.
  String values with at best a loose semantic definition. The exact use and allowed values have to be agreed between implementers.
- Classification
  Definition of the object type through classification, any regional classification system can be used. The values are defined by the classification system. This requires that both the sending and receiving program know the classification system that is used.
  The classification is a generic mechanism and its use is explained later independent of the different object types.
- Pre defined property definitions (PropertySets)
  Pre defined property sets (Pset_xyz) provide additional information about the object. The IFC model defines the data fields and their semantic meaning.
- Extended property definitions (PropertySets)
  New Property sets can be defined by the implementers and even by end users. The semantic meaning and allowed values have to be defined by the implementers.
  Extending the model using PropertySets is a generic mechanism and its use is explained later independent of the different object types.

All of these are needed for specific purposes and it is imperative that the implementers agree on the use of each of these; otherwise there will be no interoperability. User defined PropertySets should be the last resort and used only when the IFC model simply does not provide another mechanism for exchanging the information.

One approach is to select one or more primary identification methods, like project specific types, classification or manufacture information. Additional information could be used to confirm that the selected type / item can really be used.

- Thickness of the wall geometry has to match the thickness of the wall type used
- Door geometry, e.g height and width has to match the values of the door type
- Etc.

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Spaces

Class name	IfcSpace	
Pre defined types	*No pre defined types*	
User defined type	IfcSpace.UserDefinedType	
Labels and descriptive strings	IfcSpace.Label	Optional label for arbitrary use by the participating software systems or users.
	IfcSpace.InteriorOrExteriorSpace	Defines, whether the Space is interior (Internal), or exterior (External), i.e. part of the outer space.
	IfcSpace.SpaceReference	Short name for the space as used for reference purposes.
	IfcSpace.SpaceName	Long name for the space.
Pre defined PropertySets	Pset_SpaceCommon.Description	Description for this type of Space
	Pset_SpaceCommon.CodeUseType	Occupancy type, as defined in the presiding building code.
	Pset_SpaceCommon.SpaceCatalogue	Description of the space catalogue
	Pset_SpaceCommon.NaturalVentilation	Indication whether the space is ventilated natural (true) or mechanical (false).
	Pset_SpaceCommon.SprinklerProtection	Indication whether the space is sprinkler protected (true) or not (false).
Special		

Walls

Class name	IfcWall	
Pre defined types	*No pre defined types*	
User defined type	IfcWall.UserDefinedType	
Labels and descriptive strings	IfcWall.Label	Optional label for arbitrary use by the participating software systems or users.
Pre defined PropertySets	Pset_WallCommon.Reference	Reference ID for this wall type in this project (e.g. type 'A-1')
	Pset_WallCommon.Description	Textual description for this wall type.
	Pset_WallCommon.ExternalWall	Boolean value indicating if this wall is exterior
	Pset_WallCommon.FireRating	Fire rating of wall assembly.
	Pset_WallCommon.ThermalRating	Rating for thermal transmisivity ('U' value).
	Pset_WallCommon.AcousticRating	Rating for sound protection (Sound Transference Factor =STF) for wall assembly.
Special	A wall has additional layer information through the IfcSpace.LayerInformation attribute. This attribute assigns an IfclayerSet to the wall and the layer set contains information of the materials used in the layer set and the thickness of the individual material layers. In IFC R2.0 one layer can consist of only one material. IfcSpace.LayerInformation is a mandatory attribute although the complexity of most walls cannot be described by the layer set.	

Doors

Class name	IfcDoor, IfcDoorPanel, IfcDoor Lining A door can be a single IfcDoor or an assembly of IfcDoorPanel and IfcDoorLining objects.	
Pre defined types	IfcDoorPanel.PredefinedType	Swinging Sliding Revolving Rollingup

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User defined type	IfcDoor.UserDefinedType IfcDoorPanel.UserDefinedType IfcDoorLining.UserDefinedType	
Labels and descriptive strings	IfcDoor.Label	Optional label for arbitrary use by the participating software systems or users.
	IfcDoorPanel.Label	Optional label for arbitrary use by the participating software systems or users.
	IfcDoorLining.Label	Optional label for arbitrary use by the participating software systems or users.
Pre defined PropertySets	Pset_DoorCommon.Reference	Reference ID for this door type in this project (e.g. type 'D-1')
	Pset_DoorCommon.Description	Textual description for this door type.
	Pset_DoorCommon.NominalHeight	Nominal Door Height as usually specified in the product information (rounded actual height)
	Pset_DoorCommon.NominalWidth	Nominal Door Width as usually specified in the product information (rounded actual width)
	Pset_DoorCommon.HardwareGroup	Reference to the hardware group used for this door type. It is implemented as a reference to the simple property list (Pset_HardwareGroup) which defines information about the door hardware.
	Pset_DoorCommon.IsExterior	Indication whether the door type is designed for use in exterior walls (TRUE) or not (FALSE)
	Pset_DoorCommon.Infiltration	Infiltration flowrate of outside air for the filler object based on the area of the filler object at a pressure level of 50 Pascals. It shall be used, if the length of all joints in unknown. The usual unit (if pressure is taken into consideration) is m3/(hPa2/3)
	Pset_DoorCommon.ThermalTransmittanceCoefficient	Overall thermal transmittance coefficient (U-Value) of the composite materials used by the filler object. It includes internal and external surface coefficient. The usual unit is W/m²K.
	Pset_DoorCommon.FireRating	Fire rating of complete door assembly. Given according to the national fire safety classification.
	Pset_DoorCommon.AcousticRating	Rating for acoustic transmisivity (Sound Transference Factor =STF) for the complete door assembly.
	Pset_DoorCommon.SecurityRating	Index based rating system indicating security level.

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	Pset_DoorPanelCommon.StandardPanelType	Description of the standard operating type of the panel, according to the national classification system.
	Pset_DoorPanelCommon.Finish	Finish selection for this panel
	Pset_DoorPanelCommon.Color	Color selection for this panel
	Pset_DoorPanelCommon.PanelHeight	Overall height of this panel. Should be included for convinience use by applications that cannot derive this from the geometric representation.
	Pset_DoorPanelCommon.PanelWidth	Overall width of this panel. Should be included for convinience use by applications that cannot derive this from the geometric representation.
	Pset_DoorLiningCommon.LiningDepth	Depth (dimension in plane perpendicular to door leaf) of the door lining.
	Pset_DoorLiningCommon.LiningThickness	Thickness (width in plane parallel to door leaf) of the door lining.
Special	Pset_DoorPanelCommon and Pset_DoorLiningCommon contain additional information mainly for the purpose of thermal calculations. These attributes might be of limited use also for identifying the doors and its characteristics. There should also be a referene to IfcManufactureInformation	

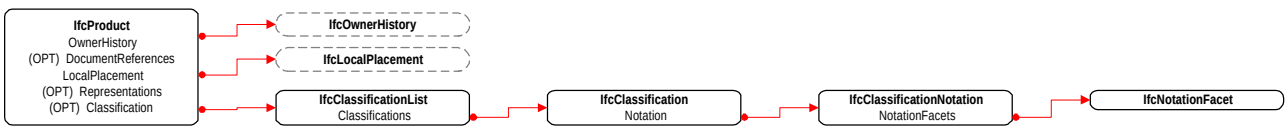
Classification

The IFCs do not define its own classification system; instead it supports existing classification systems. Because classifications are national or regional an IFC file containing classification information can only be understood in the context of the regional classification system it uses.

The subtypes of the following objects are able to use classification. Please see Appendix-A for a more detailed list.

- IfcProduct
- IfcMaterial
- IfcProcess
- IfcProject
- IfcControl
- IfcResource

The classification support in IFCs works by allowing a reference from an object into a classification system. One object may be classified using more than one system.



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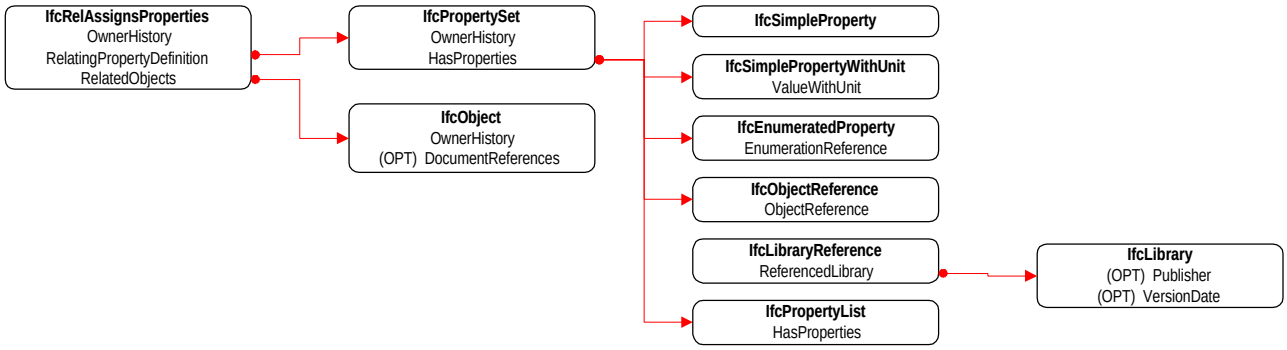
Extended property definitions

Existing objects in the IFC model can be extended by the implementers or even dynamically by the end users using the PropertySet mechanism.



For more detailed information please see Vol. 5 – IFC Software implementation guide, chapter 3 – Guidelines for implementing PropertySets

PropertySets are a powerful mechanism to extend the objects that already exist in the model. However, this power should be used with caution and the following recommendations should be followed.

- First find out what the model has to offer, extend the model only if it is absolutely necessary.
- Find out what extensions others have made and use the same extensions if they target your needs.
- Try to find consensus among multiple software vendors for the extensions before using them.
- Document and publish all extensions. Not everybody will support your extensions, but they should be given the chance to do so. If extensions are not documented and published there is also the danger of several slightly different incompatible solutions for the same problem.

How much?

The 'how much' part defines where the quantities of the object can be found.

There are three kinds of quantities in the IFC model

1. The number of instances of a certain type in the exchange file
2. Quantities derived from the object's geometry
3. Calculated attribute values

Spaces

Class name	IfcSpace
Number of instances	The number of space instances, their type and area give the space programme

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Derived quantities	The area of a space can be calculated with an algorithm that calculates the area of a polygon. In IFC R2.0 it is not possible to have spaces with holes (voids) in them. The perimeter of the space can be calculated from the polygon defining the space geometry. For simple cases (Standard geometric representation) the volume of the space can be calculated with the space area and space height.	
Calculated attribute values	IfcSpace.calcTotalPerimeter	Total Gross (physical) Perimeter of that Space. Exposed as an attribute by file-based exchange.
	IfcSpace.calcTotalArea	Total Gross (physical) Area of the floor level of that Space. Exposed as an attribute by file-based exchange.
	IfcSpace.calcTotalVolume	Total Gross (physical) Volume of that Space. Exposed as an attribute by file-based exchange.
	IfcSpace.calcAverageHeight	Floor Height (without flooring) to Ceiling height (without suspended ceiling) for this space (measured from top of slab of this space to the bottom of slab of space above); the average shall be taken if room shape is not prismatic.
	IfcSpace.calcAverageGrossHeight	Floor Height to Floor Height for this space (measured from top of slab of this space to top of slab of space above); the average shall be taken if room shape is not prismatic.
	IfcSpace.calcAverageClearHeight	Clear Height between floor level (including finish) and ceiling level (including finish and sub construction) of this space; the average shall be taken if room shape is not prismatic.
	IfcSpace.calcElevationWithFlooring	Level of flooring of this space; the average shall be taken, if the space ground surface is sloping or if there are level differences within this space.
Special	Spaces have space boundaries mainly for HVAC calculation purposes. The areas of the space boundaries could potentially be used as the areas of the inner surfaces of the space. However, the space boundaries were not originally made for quantity takeoff purposes.	

Walls

Class name	IfcWall
Number of instances	In the case of walls the number of wall instances in the file does not tell anything about wall quantities.
Derived quantities	For the standard geometric representation it is quite easy to calculate the area and volume from the geometry, even if the application does otherwise not deal with geometry. If the quantities are derived from the geometry it is important to deduct the openings from the wall quantities. This can also be done easily be non-geometric applications. For exact quantities also the wall connections have to be calculated. For the standard geometric representation the wall connections are logical connections, i.e. they don't have geometry. For advanced geometric representation the calculated attributes have to be used for get the quantities

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Calculated attribute values	IfcWall.calcWallArea	Total Gross (physical) Area of the wall. Measured as vertical wall face, perpendicular to the centre line of the wall. Exposed as an attribute by file-based exchange, particularly for receiving applications with limited (or not existing) geometric capabilities.
	IfcWall.calcWallVolume	Total Gross (physical) Volume of the wall. Exposed as an attribute by file-based exchange, particularly for receiving applications with limited (or not existing) geometric capabilities.
Special	The calculated values of the wall do not take the wall connections nor the opening elements into account. The receiving application has to deduct the opening elements and the deal with the connections. This is also true for advanced geometric representation where the wall connections can become too difficult for non-geomeric applications to calculate. IFC R2.0 is not very suitable for exact quantity takeoff of walls.	

Where?

The 'where' part defines the physical location of objects as well as the different groups the objects can belong to.

The IFC model provide several ways to examine where a specific object is located

- Basic project hierarchy
- Grouping, containment and zones
- Geometric location information through IfcLocalPlacement

Basic project hierarchy

The IFC model has a basic containment hierarchy that can serve as the first step to locate objects.

IfcProject contains IfcSite(s) contains fcBuilding(s) contains IfcBuildingStorey(s)

All building elements are contained by some IfcBuildinStorey object through an IfcRelContains objectified relationship. This is a strict containment hierarchy, which means that one object can only be contained directly by one other object, e.g. a space can only be contained by one building storey.

The basic hierarchy can be used for filtering out a subset of objects when e.g. making a quantity takeoff for a specific building storey.

Grouping (IfcRelGroups)

The use of grouping needs to be determined by the implementers.

Containment (IfcRelContains)

The use of containment needs to be determined by the implementers.

- Containment –group for furniture and other equipment inside a space
- Containment reference –group for doors and windows 'belonging' to a space

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Zones (IfcZone)

The use of zones needs to be determined by the implementers.

- Construction zone
- Security zone
- Thermal zone
- Apartment ‘zone’

Geometric location (IfcLocalPlacement)

Using the geometric information to determine the location of certain objects is a possibility, but it is not easy and the results may not be reliable.

It is possible to use a boundary polyline and the local placement point with a function that determines if a point is inside a boundary. The boundary polyline could be one from the exchange file (e.g. space) or the receiving program could create one for a specific purpose.

IfcLocalPlacement has an attribute called PlacementRelativeTo, which is a ‘logical’ connection between two objects. If a piece of furniture is placed relative to a space then it is quite safe to assume that the furniture is inside that space.

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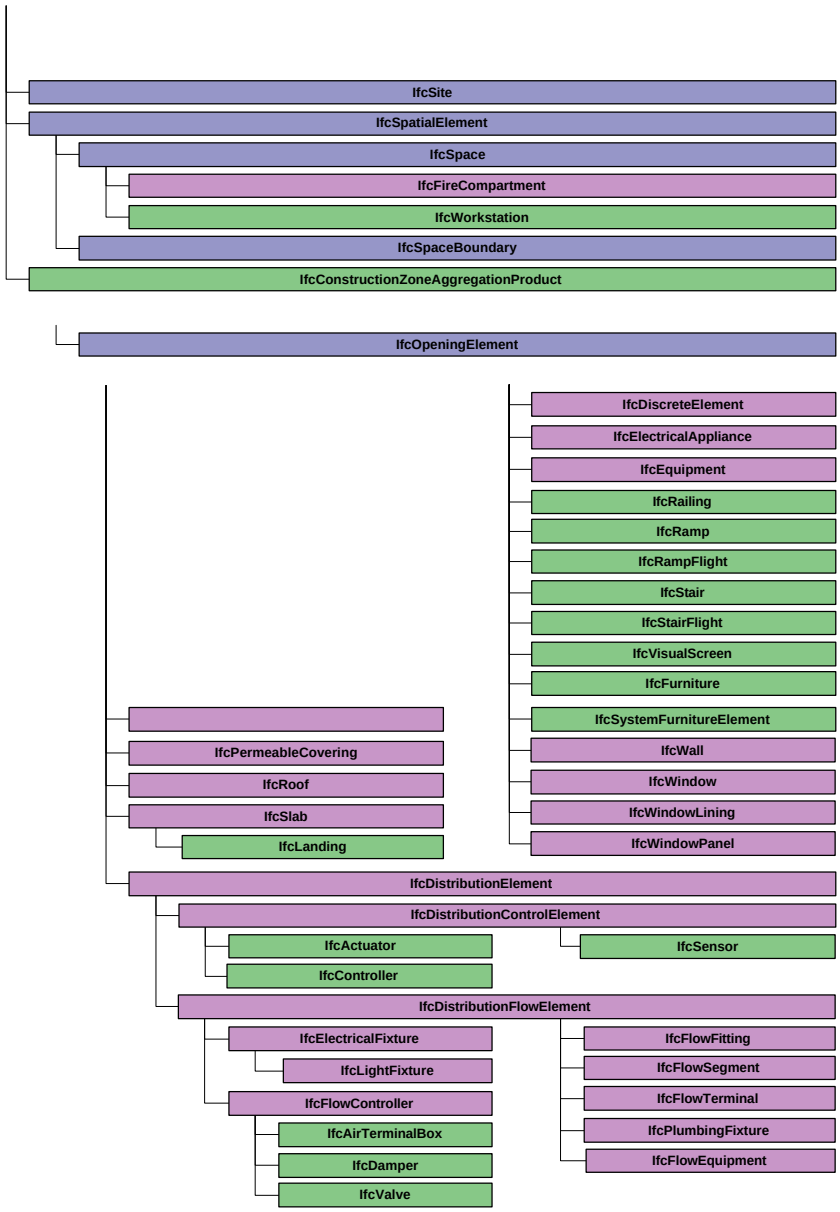
Appendix-A: Objects with classification

The ability of an object to use classification is introduced at the IfcProduct –level. This means that all subtypes of IfcProduct can use classification.



In addition to the subtypes of IfcProduct the following objects are able to use classification:

- IfcMaterial
- IfcProcess
  - IfcWorkTask
  - IfcOccupancyTask
- IfcProject
- IfcControl
  - IfcConnectionGeometry
    - IfcLineConnectionGeometry
    - IfcPointConnectionGeometry
  - IfcSpaceProgram

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    - IfcFurnitureModel
    - IfcOccupancySchedule
    - IfcScheduleTimeControl
    - IfcWorkPlan
    - IfcProjectOrder
        - IfcChangeOrder
        - IfcPurchaseOrder
        - IfcWorkOrder
    - IfcDistributionPortGeometry
    - IfcConstraint
        - IfcMetric
            - IfcMetricBenchmark
        - IfcObjective
    - IfcCMDocPackage
    - IfcOccupancyScheduleElement
    - IfcWorkScheduleElement
    - IfcWorkSchedule
    - IfcCostElement
    - IfcCostSchedule
        - IfcBudget
    - IfcApproval
    - IfcMaintenanceRecord
    - IfcMaintenanceType
- IfcResource
    - IfcProductResource
    - IfcConstructionEquipmentResource
    - IfcLaborResource
    - IfcCrewResource
    - IfcConstructionMaterialResource
    - IfcSubcontractResource

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