13FP7 – 285229 – Collaborative Project

Knowledge-based energy management for public buildings through holistic information modelling and 3D visualization

KnoholEM

Deliverable 4.4: Integration of Concepts with IFC Standard

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1 EXECUTIVE SUMMARY

The delivery report 4.4 “Integration of concepts with IFC standard” describes the work performed in work package 4 and refers to the task 4.5 “Integration of models with existing standards”. This work integrates concepts uncovered within the KnoHolEM project with the Industry Foundation Classes (IFC) building information model, using an established technique: the Information Delivery Manual (IDM).

The main purpose of the IDM is to facilitate the integration of concepts with the existing IFC standard, and where such concepts do not exist in the IFC standard, to make recommendations for their inclusion. The secondary purpose of the IDM is to facilitate communication and analysis of the KnoHolEM processes both within the project and also to a wider audience.

The IDM model presented here covers a use case which forms the basis of the KnoHolEM solution. The processes must be carried out and the information exchanges presented here must be met to enable the KnoHolEM solution. The processes are aligned with each work packages (WP) through extensive consultation with the respective WP leaders and can be explored in greater detail by consulting the referenced deliverables.

2 Contents

3 INFORMATION DELIVERY MANUAL FOR KNOHOLEM

3.1 Introduction

The KnoHolEM solution integrates a number of fields of expertise in areas such as: ontologies, sensors, sensor communication, data mining, sensitivity analysis, visualisation and simulation. A methodology was required to document and communicate amongst these experts the different processes and information exchanges required to support the KnoHolEM solution. For this purpose, the Information Delivery Manual (IDM) was chosen. IDM has been developed by the National Building Information Model Standard Committee (NBIMS) to document the processes involved to complete specific use cases. A use case defines tasks (also referred to here as processes) and data exchanges required to complete those tasks. IDM provides a formal structured methodology to capture use cases and then align required information exchanges with existing standards, such as the Industry Foundation Classes (IFC). IDMs also facilitate sharing of use cases among domain experts who can review and recommend changes to improve the overall quality. IDMs can also be re-used or adjusted by other domain experts who wish to define their own use cases [1]. IDM is useful both within a project for internal communication and also outside a project, for dissemination of developed use cases to wider communities, e.g. the architecture, engineering and construction (AEC) communities. Due to the lack of an available manual for implementing IDM, guidelines set down by the European FP7 project HESMOS, who have published their findings in the publicly available document: 'Information Delivery Manual Work within HESMOS' [2], have been followed.

Once a use case has been defined by the appropriate expert in that field, and the different information exchanges identified, it is the job of software engineers to implement the tools to support the defined use cases. IDM supports this process by providing a comprehensive means for mapping data exchange requirements to Model View Definitions (MVDs). MVD is the standard methodology and format for documenting the software implementation requirements for standard IFC based data exchange. The MVD decouples the tool designer from the tool software developer, allowing the MVDs be structured such that different audiences can focus on the information relevant to them. By maintaining this distinction, requirements of the data model can be quickly mapped to new software when new technologies become available. IDMs and MVDs therefore support a process by which multiple disciplines can develop and communicate their solution and to specify the exact data exchange requirements to support integration with other related tools. Unfortunately, the MVD process is also poorly documented and will only become formalised in the release of IFC2x4. Therefore, to date, we have only applied the IDM process to the modelling of information exchanges within the KnoHolEM project and while these have been implemented in our software solution, as yet, the MVD models have not been created.

3.2 Using the Information Delivery Manual

IDM offers a standard method for answering the following questions related to each use case [2].

- Who are the actors (those who require information from the BIM)?
- When is information needed (in relation to other tasks)?
- What is the minimal amount of data required?

The IDM begins with an overview of the use case, describing who the beneficiaries are, when in the building life cycle it takes place and a brief description of the required input data, and finally the outcome of the use case. The 'who' is described in tabular form, which names and describes each actor involved in the use case. These are then presented along with the 'when' using the Business Process Modelling Language (BPMN) [3], which is a graphical model based upon the Unified Modelling Language [4] activity diagrams. The required information exchange is captured in tabular form, which described the type of data needed and also aligns the data to existing standards and the KnoHolEM ontology described in WP1 and WP2. In the next section we present the developed IDM which captures the different processes and tasks required to enable the KnoHolEM solution.

3.3 KnoHolEM IDM Process Overview

The following section gives first an overview of the use case which drives the data requirements of the KnoHolEM solution. Subsequent sections break down the different tasks/processes presented in the overview diagram (Figure 1) into sub-tasks/processes which are then explored in further detail. For each presented BPMN process model, the IDM first gives an overview explaining the main purpose of the process model, then the actors involved followed by the BPMN model. Finally, for all but the overview BPMN, the data requirements are captured in tabular form.

This use case describes a method for **supporting facility managers and those interested in reducing energy costs in the building(s)** by facilitating monitoring of energy use within a building(s) and by providing suggestions to improve the energy efficiency of zones. The solution is deployed during the operational phase of the Building Life Cycle (BLC). It takes into account as input the following data:

- Building layout including the layout and configuration of zones
- Location and types of sensor deployments
- Location and types of conditioning systems including lighting, HVAC, etc.
- Type of building control system.
- Type of energy management system.
- Building usage including functional use and occupancy of zones (determined through sensor data and user input)
- Building construction including the r values of all construction elements including walls, floors, roofs/ceilings, windows, doors and the like
- Weather data

The facility manager is presented with a building visualisation tool which supports selection of zones within the building, provides historical sensor readings and comparisons of historical average energy consumption with current energy consumption and periodically generates suggestions to the facility manager on action to take to improve the energy efficiency of a zone based upon the historical and current usage of the building.

The **energy management tool supports the following features**:

- periodic suggestion generation for energy efficient use of zones based upon rules generated from the historical use of the building and energy simulation data
- assessment of the space and building energy performance using data visualisation
- overall estimate of the energy use by zones and for the building and a comparison with current energy use

For the purposes of this process map, energy simulation is considered to include the assessment of heating and cooling demand within a building. Various types of analysis are within the scope of this process map including:

- Setting comfort criteria for spaces including minimum and maximum required indoor air temperatures (summer and winter), minimum fresh air requirements.
- Simple heat loss/gain calculations based on minimal data provision.
- Detailed heat loss/gain calculations using well defined analytical methods.
- Energy labelling calculations using analysis methods mandated by legislation.
- Analysis of energy consumption in meeting the building energy demands.
- Optimisation of energy performance related to fuel type for lifecycle cost, environmental impact issues, comfort aspects.

3.3.1 Actors: KnoHolEM Overview

The primary roles shown in the process model diagram (as "swimlanes") are defined in Table 1;

Table 1 KnoHolEM Actors

Actor	Description
Ontology Expert	Extracts required data from available resources and populates ontology with assertions (a-box).
Communications Expert	Determines requirements of communications gateway to communicate with building systems (Building Control System, Building Management System, Sensors, Devices, etc.).
Data Mining and SWRL Rule Generation Expert	Generates rules from all available data and outputs as SWRL rules (r-box).
Real-Time Controller Expert	Installs and maintains Real Time (RT) - controller.
Visualisation Expert	Integrates available data sources into visualisation interface.
Facilities Manager (and Occupants)	Manages building energy consumption. Occupant can contribute to knowledge-base through entering of activities.
Energy Simulation Expert	Develops energy model for building.
Sensitivity Analysis Expert	Generates rules based upon energy model.

3.3.2 BPMN: KnoHolEM Overview

The BPMN overview of the processes required to enable the KnoHolEM solution.

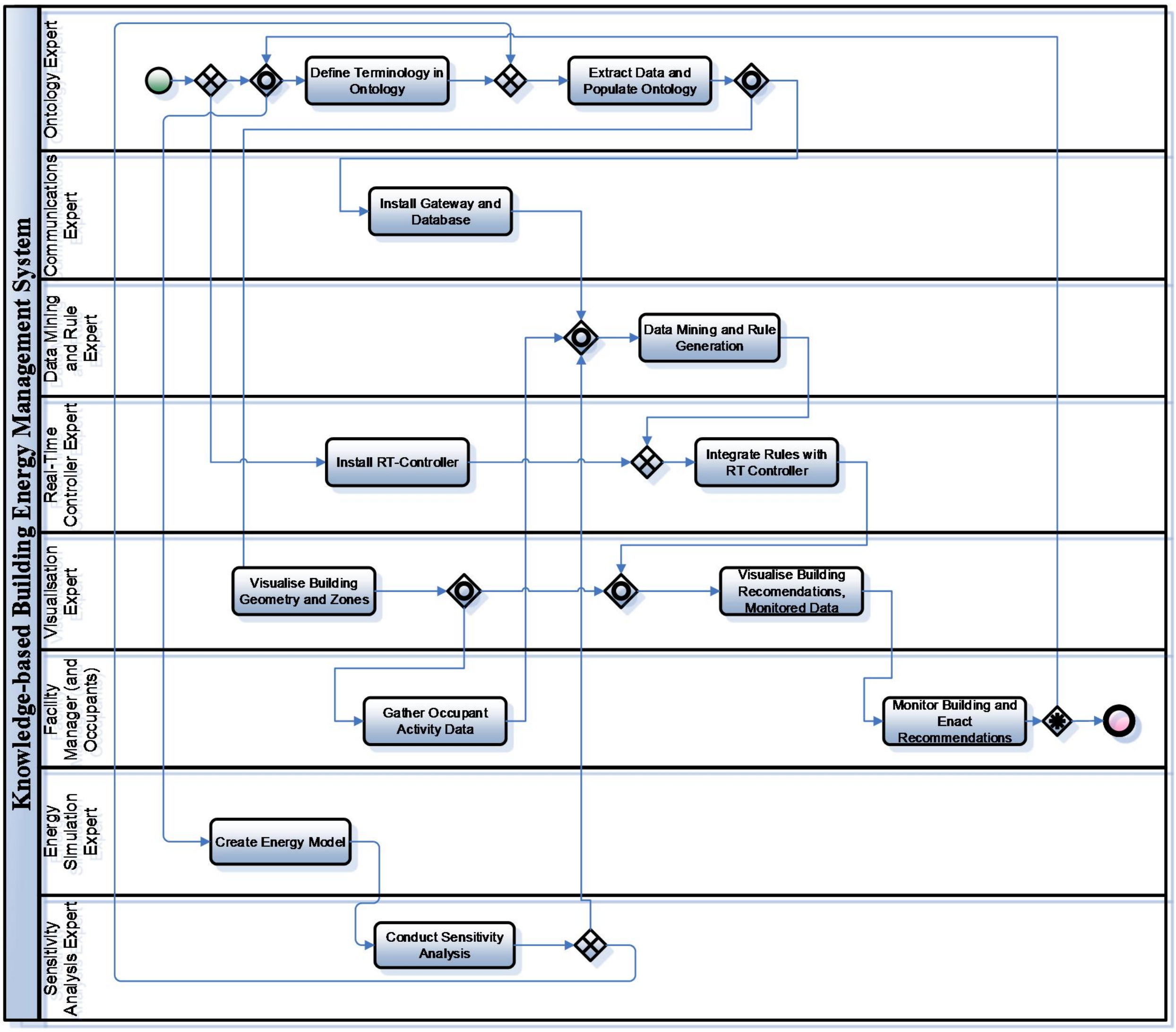

Figure 1 KnoHolEM Overview BPMN

3.3.3 List of Sub-Processes

The table below lists all identified sub-processes/tasks shown in Figure 1 by name, description of task and the input data/exchange requirement (ER) required by the process and output data generated by the process.

Table 2 Overview List of Processes

Type	Name	Description	Input	Output
Sub-Process (Collapsed)	Define Terminology in Ontology	Align ifc terminology with owl concepts (through class annotation).	ifc_schema (ER)	building_ontology_t-box (owl) (ER)
Sub-Process (Collapsed)	Extract Data and Create Ontology	Collect all available building data. Determine Zones and placement of sensors/devices. Populate ontology.	Geometry models, sensor descriptions, hvac descriptions,	building_ontology_a-box (owl) (ER)

			etc. (ifc/dwg/pdf /csv/doc) (ER)	
Sub-Process (Collapsed)	Install Gateway and Database	Determine the existing Building Control Systems, Building Management Systems and any additional Sensors and Devices for communication with database (db). Install Gateway and Host db to store data instances.	communications_ interface (ER)	generic_ gateway, data_ instances (ER)
Sub-Process (Collapsed)	Visualise Building Geometry and Zones	Extract visualisation data from existing data model, or develop model by hand. Import owl ontology and align zones with geometry and visualise.	geometry_models (Ifc/dwg) (ER)	visualisation_model (ER)
Sub-Process (Collapsed)	Gather Occupant Activity Data	Visualise Building Geometry and Zones. Distribute activity modelling interface with building occupants and collect activity data.	visualisation_model, google_events (ER)	activity_ model (ER)
Sub-Process (Collapsed)	Create Energy Model	Develops Energy Model for Building	geometry models, sensor descriptions, hvac descriptions, activity_models, etc. Ifc/dwg/pdf/csv/doc (ER)	energy_model (ER)
Sub-Process (Collapsed)	Conduct Sensitivity Analysis	Conducts Sensitivity Analysis for rule generation	energy_model (ER)	building_rules (sql_instance) (ER)
Sub-Process (Collapsed)	Data Mining and Rule Generation	Collect historic sensor, device, activity and simulated data. Generate rules.	data_ instances (ER)	building_rules (sql_instance) (ER)
Sub-Process (Collapsed)	Install RT-Controller	Install RT-Controller		
Sub-Process (Collapsed)	Integrate Rules with RT-Controller	Integrate OWL_SWRL rules with. RT-Controller periodically reads all available data instances and generates recommendations using rule engine.	owl_swrl, sensor_instances (ER)	er_ recommendations (ER)
Sub-Process (Collapsed)	Visualise Building Recommendations, Monitored Data	Displays generated recommendations for a selected zone. Also displays historic sensor data, current sensor data and indicates when current is greater than historic average.	data_instances (ER)	
Sub-Process (Collapsed)	Monitor Building and Enact Recommendations	Iterative process of enacting recommendations and monitoring data to determine most energy efficient configurations of building systems.	data_instances (ER)	logged_changes _instances

3.4 Sub-process: Extract Data and Create Ontology

3.4.1 Overview: Extract Data and Create Ontology

Before the KnoHolEM solution can be applied to a building, all relevant and available data must be extracted from existing sources. Firstly, an ontology of terms must be created (the t-box ontology). Here all the concepts which are relevant to the energy saving solution must be captured. As a basis for this the IFC 2x3 schema is used, and so the concepts are aligned with the IFC schema. Concepts not covered within IFC2x3 are also created. Together these make up the t-box ontology. Next, all available building data is gathered and is used to populate the ontology with assertions (the a-box ontology), for example the names and positions of sensors, placement and perimeters of zones, etc. Together, this results in the a-box ontology. Finally, zones of interest to the energy saving solution are identified and added to the a-box ontology. This process is described in greater detail in deliverables D2.1, D2.2.

3.4.2 Actor(s): Extract Data and Create Ontology

Actor	Description
Ontology Expert	Extracts required data from available resources and create an ontology of terminology (t-box ontology) and also populates this ontology with assertions (a-box ontology).

3.4.3 BPMN: Extract Data and Create Ontology

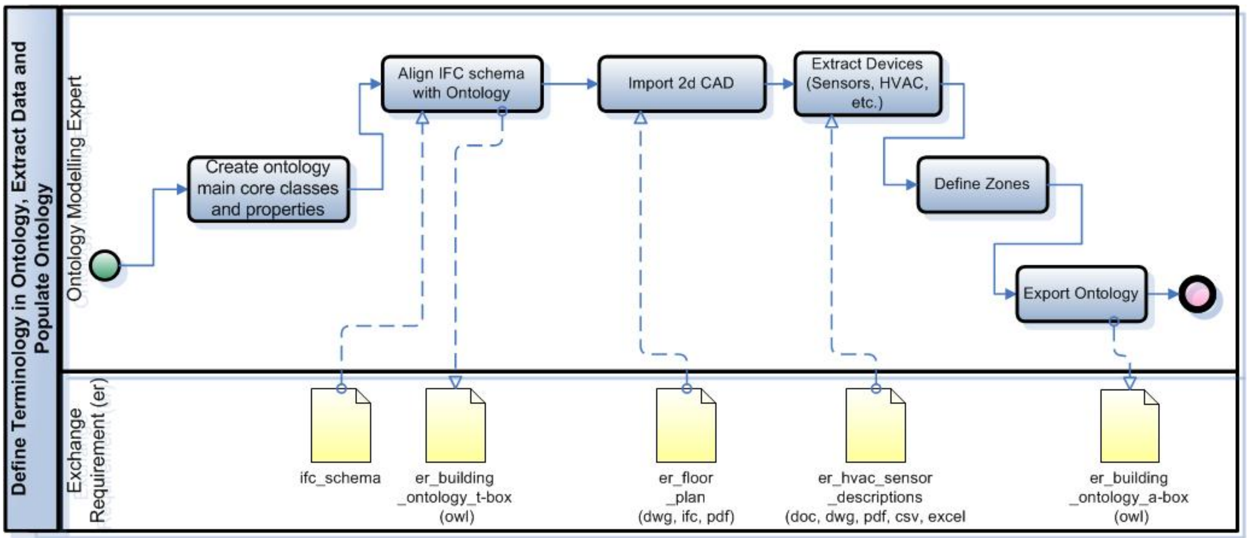

Figure 2 Extract Data and Create Ontology BPMN

3.4.4 Information Requirements Input: Extract Data and Create Ontology

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc 2x3	owl:knoholem*
Project	The following properties should be included:		String	n/a	X	IfcProject	c:Project
	Identification		String	n/a	X	IfcGloballyUniqueId	uri
	Owner/Client Information		String	n/a		IfcOwnerHistory	e:Prov-o
	Model Author	Responsible Actor for creating model.	String	n/a		IfcActor	o:Actor
Building	The following properties should be included:					IfcBuilding	c:Building
	Identification		String	n/a	X	IfcGloballyUniqueId	uri
	Global Coordinates		String	deg/min/sec		IfcSite.RefLatitute/.RefLongitude	o:Placement
	Orientation	Deviation of building grid from true north, clockwise	Real	Angular degrees		IfcGeometricRepresentationContext.TrueNorth	o:Placement
	Elevation	Relative to site datum	Real	m		IfcSite.RefElevation	o:Placement
	2D Geometry		dwg		X	IfcRepresentation	o:VisualRepresentation
	3D Geometry		Ifc/sketchup			IfcRepresentation	o:VisualRepresentation
Building Stories	The following properties should be included:					IfcBuildingStorey	c:BuildingStorey
	Identification		String	n/a	X	IfcGloballyUniqueId	uri
	Elevation	Relative to building datum	Real	m	X	IfcLengthMeasure	d:floorHeight
Structural Element In addition to those provided within the geometry model)	The following properties should be included					IfcBuildingElement	c:StructuralElement
	Identification		String			IfcGloballyUniqueId	uri
	Description		String				d:hasDescription
	Device Type		String			IfcLabel	d:hasType
	Placement		String			IfcPlacement	o:Placement
	Geometric Properties		String			IfcRepresentation	o:VisualRepresentation

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc 2x3	owl:knoholem*
HVAC	The following properties should be included					IfcDistributionElementType	c:BuildingControl
	Identification		String	n/a		IfcGloballyUniqueId	uri
	Description		String	n/a		IfcLabel	d:hasDescription
	Device Type		Enum**	n/a		IfcLabel	d:hasType
	Placement		String	n/a		IfcPlacement	o:Placement
	Set Point		Real			IfcUnit	d:hasSetPoint
Sensors	The following properties should be included					IfcSensorType	c:Sensor
	Identification		String	n/a	x	IfcGloballyUniqueId	uri
	Description		String	n/a	x		d:hasDescription
	Device Type		Enum	n/a	x	IfcLabel	d:hasType
	Placement		String	n/a	x	IfcPlacement	o:Placement
	Measurement Unit		String			IfcUnit	d:hasMeasurementUnit

3.4.5 Information Requirements Outputs (In addition to those given as inputs): Extract Data and Create Ontology

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	Ifc: 2x3	owl:knoholem
Zones	The following properties should be included (if not known then probable values should be used):					IfcZone	Zone
	Identification		String	n/a	x	IfcGloballyUniqueId	uri
	Description		String	n/a	x		d:hasDescription
	Zone Type		Enum	n/a	x	IfcLabel	d:hasType
	Zone Symbolic Name		String	n/a	x	IfcLabel	d:hasSymbolicName
	Zone Placement		String	n/a	x	IfcPlacement	o:Placement
	Zone Perimeters		String	n/a		IfcRepresentation	d:hasPerimeters
	hasSubZone		String	n/a		IfcRelDecomposes	o:Zone
	hasSensor/HVAC/Device/StructuralElement		String	n/a	x	IfcRelDecomposes	o:Sensor/BuildingControl/

Notes: *The following key applies to the owl ontology: c = concept in ontology, o = object property, d = data property, e = external ontology

**References to Enum types (These are categorized according to IFC Schema 2x3 and need only be provided as Strings by Demo Objects)

3.5 Sub-process: Install Gateway and Database

3.5.1 Overview: Install Gateway and Database

The KnoHolEM solution requires that a communications gateway be created between the building systems (Building Control Systems, Building Management Systems, Lighting and HVAC Systems, Sensor Networks, etc.). In this process, the communication protocols are analyzed and the 'generic gateway' to support communication between the KnoHolEM solution and the building systems, is deployed. A database host is also created to store historical and real time data. This process is described in greater detail in DR3.4.

3.5.2 Actor(s): Extract Data and Create Ontology

Actor	Description
Ontology Expert	Extracts required data from available resources and populates ontology with assertions (a-box).

3.5.3 BPMN: Install Gateway and Database

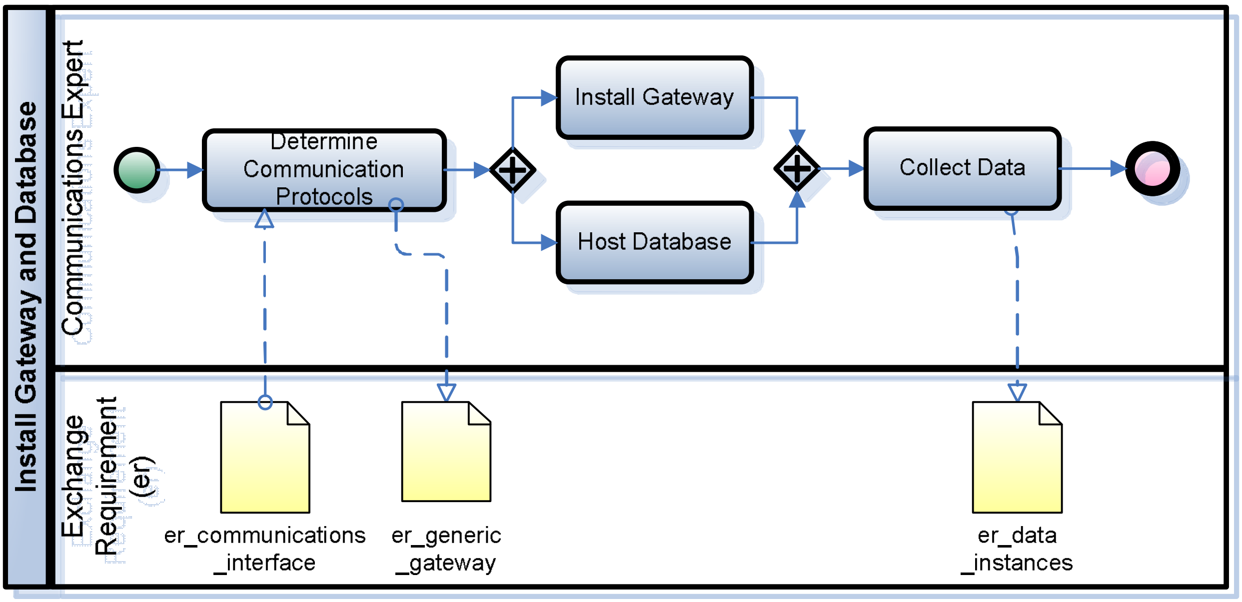

Figure 3 Install Gateway and Database BPMN

3.5.4 Information Requirements Inputs: Install Gateway and Database

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc	owl
Communication Interface	The following properties should be included						c:Interface
	Identification		String	n/a	x	IfcLabel	uri
	Description		String	n/a	x	IfcLabel	d:hasDescription
	Device Type		Enum	n/a	x	IfcLabel	d:hasType
	Inputs		String	n/a	x	IfcLabel	d:hasInputs
	Outputs		String			IfcLabel	d:hasOutputs

3.5.5 Information Requirements Outputs: Install Gateway and Database

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc	owl
Data Instance Generated periodically by devices, (e.g. HVAC, sensors)	The following properties should be included					IFC does not store data instances	Zone
	Identification		String	n/a	x	“	uri
	Description		String	n/a	x	“	d:hasDescription
	Type		Enum	n/a	x	“	d:hasType
	DateTime		String	n/a	x	“	d:hasDateTime
	DataType		String	n/a	x	“	d:hasDataType
	Unit		String	n/a	x	“	d:hasUnit
	Value		String	n/a	x	“	d:hasValue
	Zone		String	n/a	x	“	o:Zone

3.6 Sub-process: Visualise Building Geometry and Zones

3.6.1 Overview: Visualise Building Geometry and Zones

This process gives a list of data required for building visualization to meet the requirements of the process 'Visualise Building Geometry and Zones'. These include three processes for visualizing the building geometry, which are described in deliverable D4.2. It also captures the process for aligning the building ontology, captured in the previous extract data and create ontology process, with the geometry visualization, also available in D4.2.

3.6.2 Actor(s): Visualise Building Geometry and Zones

Actor	Description
Visualisation Expert	Develops the model required for visualisation of the building geometry (a floor plan). Where necessary aligns the Zone model with the developed geometry model.

3.6.3 BPMN: Visualise Building Geometry and Zones

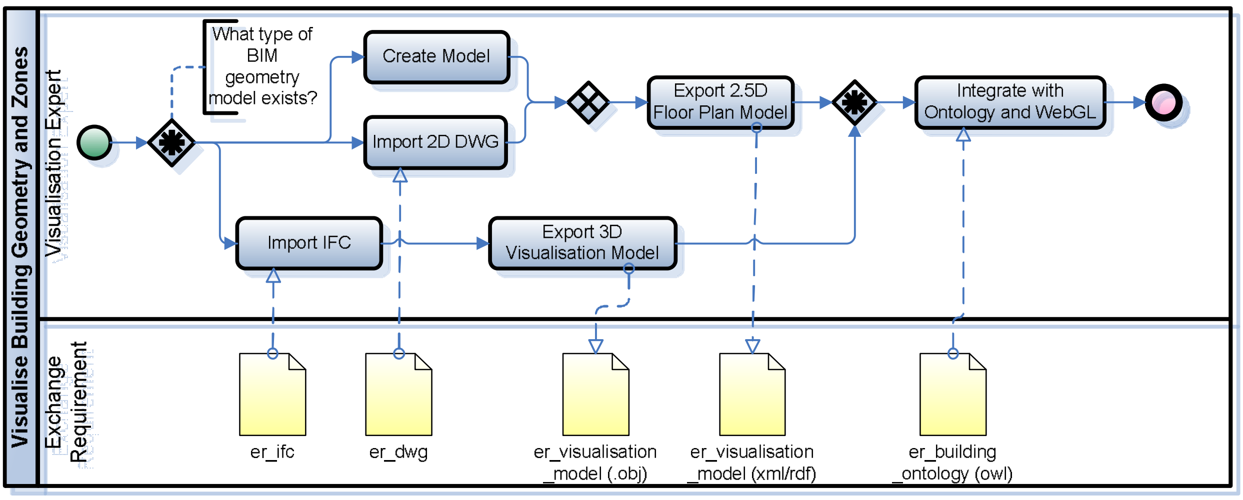

Figure 4 Visualise Building Geometry and Zones BPMN

3.6.4 Information Requirements Inputs: Visualise Building Geometry and Zones

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc	owl
Project	The following properties should be included:					IfcProject	c:Project
	Identification		String	n/a	X	IfcGloballyUniqueId	uri
	Owner/Client Information		String	n/a		IfcOwnerHistory	e:Prov-o
	Model Author	Responsible Actor for creating model.	String	n/a		IfcPerson	c:Actor
Building	The following properties should be included:					IfcBuilding	c:Building
	Identification		String	n/a	X	IfcGloballyUniqueId	uri
	Global Coordinates		String	deg/min/sec		IfcSite.RefLatitute/.RefLongitude	o:Placement
	Orientation	Deviation of building grid from true north, clockwise	Real	Angular degrees		IfcGeometricRepresentationContext.TrueNorth	o:Placement
	Elevation	Relative to site datum	Real	m		IfcSite.RefElevation	o:Placement
	2D Geometry		dwg			IfcRepresentation	o:VisualRepresentation
	3D Geometry		Ifc/skethup			IfcRepresentation	o:VisualRepresentation
Building Stories	The following properties should be included:					IfcBuildingStorey	c:BuildingStorey
	Identification		String	n/a	X	IfcGloballyUniqueId	uri
	Elevation	Relative to building datum	Real	m	X	IfcLengthMeasure	d:floorHeight
Zones	The following properties should be included (if not known then probable values should be used):					IfcZone	o:Zone
	Identification		String	n/a	x	IfcGloballyUniqueId	uri
	Description		String	n/a	x		d:hasDescription
	Zone Type		Enum	n/a	x	IfcLabel	d:hasType
	Zone Symbolic Name		String	n/a	x	IfcPlacement	d:hasSymbolicName
	Zone Placement		String	n/a	x	IfcRepresentation	o:Placement

3.7 Sub-process: Gather Occupant Activity Data

3.7.1 Overview: Gather Occupant Activity Data

In this process, the task of integrating the visualisation model with the activity modelling tool to make the process of collecting activity data possible (i.e. visualisation of building geometry and zones with identification), is shown. The Facility Manager then distributes the Activity Modeller to the occupants who provide information on their activities by entering them into the interface (when they enter and leave the building, when they have lunch and any other meetings which take place). They may also import meeting events from an existing calendar (e.g. google calendar). More information on these process are available in D2.2 and D4.2.

3.7.2 Actor(s): Gather Occupant Activity Data

Actor(s)	Description
Activity Modelling Expert	Develops the activity model to collect data on the activities of users.
Facility Manager	Distributes the activity modeller interface.
Occupant	Provides data on occupants to the knowledge-base.

3.7.3 BPMN: Gather Occupant Activity Data

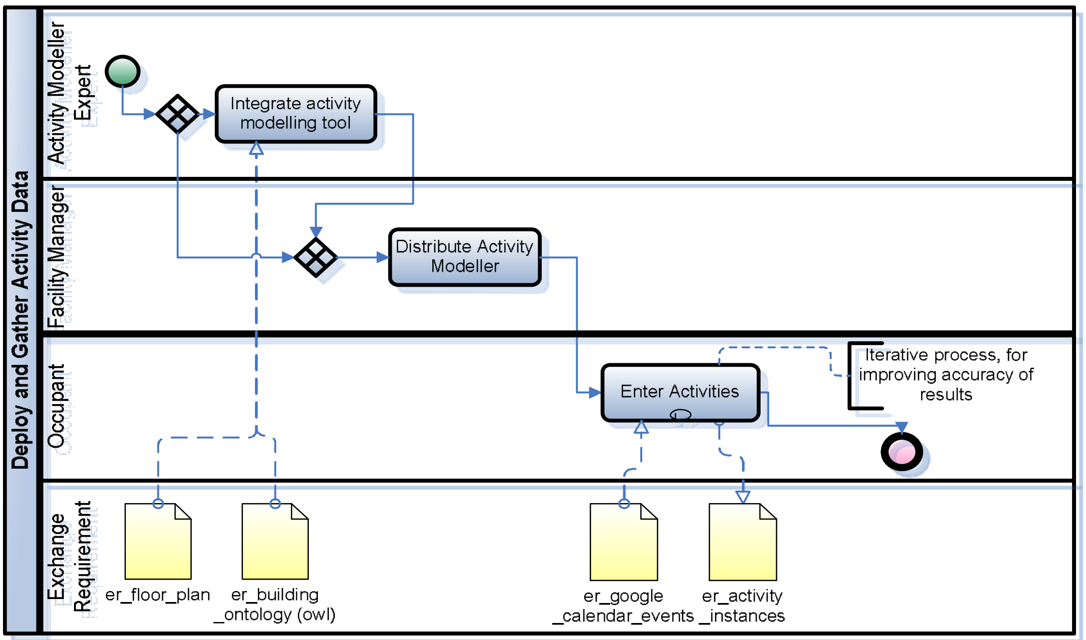

Figure 5 Gather Occupant Data BPMN

3.7.4 Information Requirements Inputs: Gather Occupant Activity Data

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc	owl:knoholem
Building	The following properties should be included:					IfcBuilding	c:Building
	Identification		String		x	IfcGloballyUniqueId	uri
	2D Geometry	Identification	String	n/a	x	IfcGloballyUniqueId	uri
		line	Number		x	IfcRepresentation	o:Line
Building Stories	The following properties should be included:					IfcBuildingStorey	c:BuildingStorey
	Identification		String	n/a	X	IfcGloballyUniqueId	uri
	Elevation	Relative to building datum	Real	m	X	IfcLengthMeasure	d:floorHeight
Zones	The following properties should be included						o:Zone
	Identification		String	n/a	x	IfcGloballyUniqueId	uri
	Description		String	n/a	x		d:hasDescription
	Zone Type		Enum	n/a	x	IfcLabel	d:hasType
	Zone Symbolic Name		String	n/a	x	IfcPlacement	d:hasSymbolicName
	Zone Placement		String	n/a	x	IfcRepresentation	o:Placement

3.7.5 Information Requirements Outputs: Gather Occupant Activity Data

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	Ifc: 2x3	owl:knoholem
Scheduled Activity Instance	The following properties should be included (if not known then probable values should be used):						c:ScheduledActivity
	Identification		String	n/a	x	IfcGloballyUniqueId	uri
	Type		Enum	n/a	x	IfcLabel	d:activityType
	Start Time		Time	n/a	x	IfcDateAndTime	d:startTime

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	Ifc: 2x3	owl:knoholem
	Start Date		Date	n/a	x	IfcDateAndTime	d:startDate
	Duration		String	miliseconds	x	IfcValue	d:duration
	hasZone		String	n/a	x	IfcZone	o:Zone
	hasUser		String	n/a	x	IfcActor	o:User

3.8 Sub-process: Create Energy Model

3.8.1 Overview: Create Energy Model

In this process the development of the energy simulation is presented. Where no 3D model is available, the energy modeller must create the 3D model by hand in the appropriate software. This requires at the least a 2D floor plan and information on the elevation of the floors. The energy simulation results in an energy model which is then used to inform the rule engine. The outputs of the energy simulation are large and as such at user discretion and not included here. For more information, see deliverable D5.1 and D5.4.

3.8.2 Actor(s): Create Energy Model

Actor(s)	Description
Energy Modelling Expert	Develops the energy model for the building. This is used as input for the rule engine.

3.8.3 BPMN: Create Energy Model

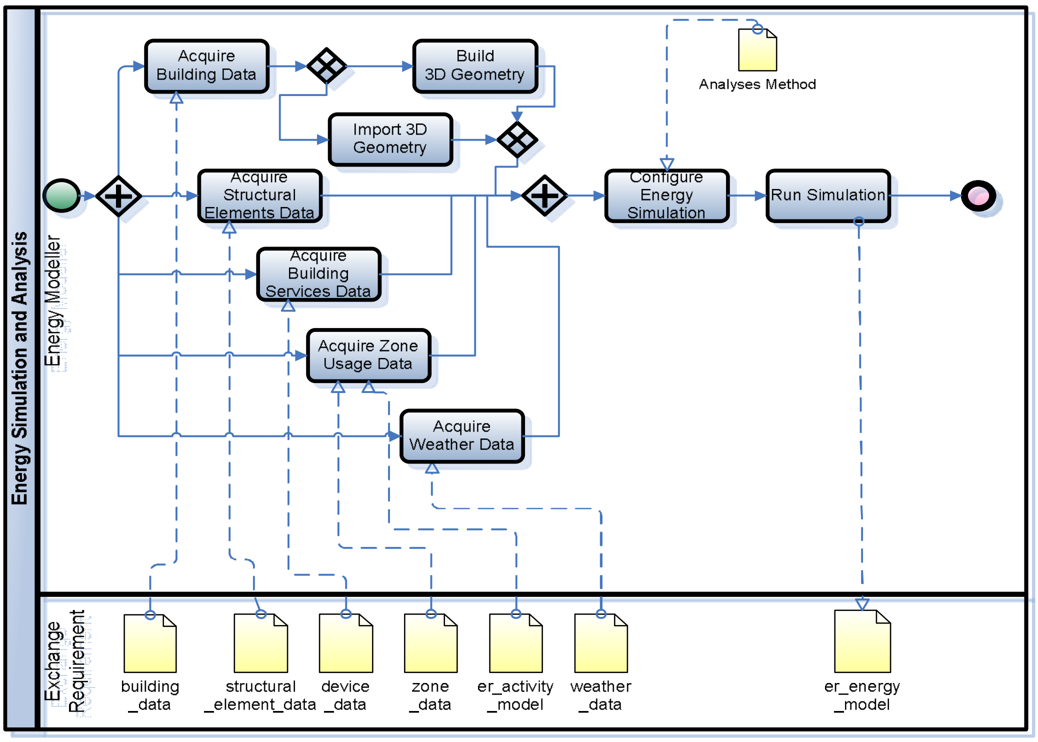

Figure 6 Create Energy Model BPMN

3.8.4 Information Requirements Inputs: Create Energy Model

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc 2x3	owl:knoholem
Building	The following properties should be included:						
	Identification		String	n/a	X	IfcGloballyUniqueId	uri
	Global Coordinates		String	deg/min/sec	X	IfcSite.RefLatitute/.RefLongitude	c:Placement
	Orientation	Deviation of building grid from true north, clockwise	Real	Angular degrees	X	IfcGeometricRepresentationContext.TrueNorth	c:Placement
	Elevation	Relative to site datum	Real	m	X	IfcSite.RefElevation	c:Placement
	2D Geometry	Colour coded to indicate service methods for each space (i.e. full air conditioning, mech, or natural ventilation)	dwg/pdf		X	IfcRepresentation	c:VisualRepresentation
	3D Geometry		ifc/sketchup				c:VisualRepresentation
	Window Schedules	Plans indicating number of opening windows if natural ventilation used Indication of opening restrictions on any windows if natural ventilation used	Excel, pdf, doc, etc.		X	IfcTimeSeriesSchedule	c:BuildingControl
	External Shading	Are external overhangs/other brise soleil shown on elevations where present. Elevation drawings need to show these in place and an unobstructed view of façade behind them.	Excel, pdf, doc, etc.		X	IfcBuildingElement	c:BuildingElement
	Servicing Type	Natural ventilation, Mech. ventilation, AC or combination.	Excel, pdf, doc, etc.		X	IfcControllerType	c:BuildingControl
	Servicing Method	Heating system method and cooling system method if applicable.	Excel, pdf, doc, etc.		X	IfcControllerType	c:BuildingControl
Building Stories	The following properties should be included:					IfcBuildingStorey	
	Identification		String	n/a	X	IfcGloballyUniqueId	uri
	Elevation	external floor to floor level heights	Real	m	X	IfcLengthMeasure	d:floorHeight
Structural	The following properties should be included (opaque fabric details, external door types					IfcBuildingElement	

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc 2x3	owl:knoholem
Element In addition to those provided within the geometry model)	and construction details, glazing and frame details.						
	Identification		String		X	IfcGloballyUniqueId	uri
	Description		String		X		d:hasDescription
	Placement		String		X	IfcPlacement	c:Placement
	Geometric Properties		String		X	IfcRepresentation	c:VisualRepresentation
	U-values	(If known)	Real			IfcValue	d:hasUValue
HVAC	The following properties should be included					IfcDistributionElementType	c:BuildingControl
	Identification		String	n/a		IfcGloballyUniqueId	uri
	Description		String	n/a			d:hasDescription
	Device Type		Enum	n/a		IfcLabel	d:hasType
	Placement		String	n/a		IfcPlacement	c:Placement
	Heating Set Point		Real			IfcUnit	d:hasHeatingSetPoint
	Cooling Set Point		Real			IfcUnit	d:hasCoolingSetPoint
Zone	The following properties should be included					IfcSensorType	c:Sensor
	Identification		String	n/a	x	IfcGloballyUniqueId	uri
	Zone Type		String	n/a	x	IfcLabel	d:hasDescription
	Placement		String	n/a	x	IfcPlacement	c:Placement
Zone (Internal gain) (a sub-type of zone)	The following properties should be included						n/a
	Infiltration rate	Includes unit, value and hours of operation	String			IfcUnit, IfcValue	n/a
	Mechanical Ventilation	Includes unit, value and hours of operation	String			IfcUnit, IfcValue	n/a
	Occupancy Sensible gain	Includes unit, value and hours of operation	String			IfcUnit, IfcValue	n/a
	Occupancy Latent Gain	Includes unit, value and hours of operation	String			IfcUnit, IfcValue	n/a
	Equipment Sensible Gain	Includes unit, value and hours of operation	String			IfcUnit, IfcValue	n/a
	Cooling Emitter	Radiative, Convective or both	String			IfcUnit, IfcValue	n/a
	Heating Emitter	Radiative, Convective or both	String			IfcUnit, IfcValue	n/a

3.9 Sub-process: Conduct Sensitivity Analysis and Develop Rules

3.9.1 Overview: Conduct Sensitivity Analysis and Develop Rules

This process is concerned with developing rules from the energy simulation developed in the task 'Create Energy Model'. It begins with a pre-processing stage, in which the simulation model is converted into a format which can be used for the ANN training testing task. If the correct error rate is met, then the network can be trained. One completed, the genetic algorithm can be employed. This is covered by a separate sub-process. Here, sensor data is used to drive the ANN-based rule generation. The resulting SWRL rules are stored in a database along with weights. This is a continuous process, and ceases only when all possible rules have been generated. For more in depth description of this process, consult DR2.4 and here [5].

3.9.2 Actor(s): Conduct Sensitivity Analysis and Develop Rules

Actor(s)	Description
Sensitivity Analyst and Rule Generation Expert	Generates rules from energy simulation

3.9.3 BPMN: Conduct Sensitivity Analysis and Develop Rules

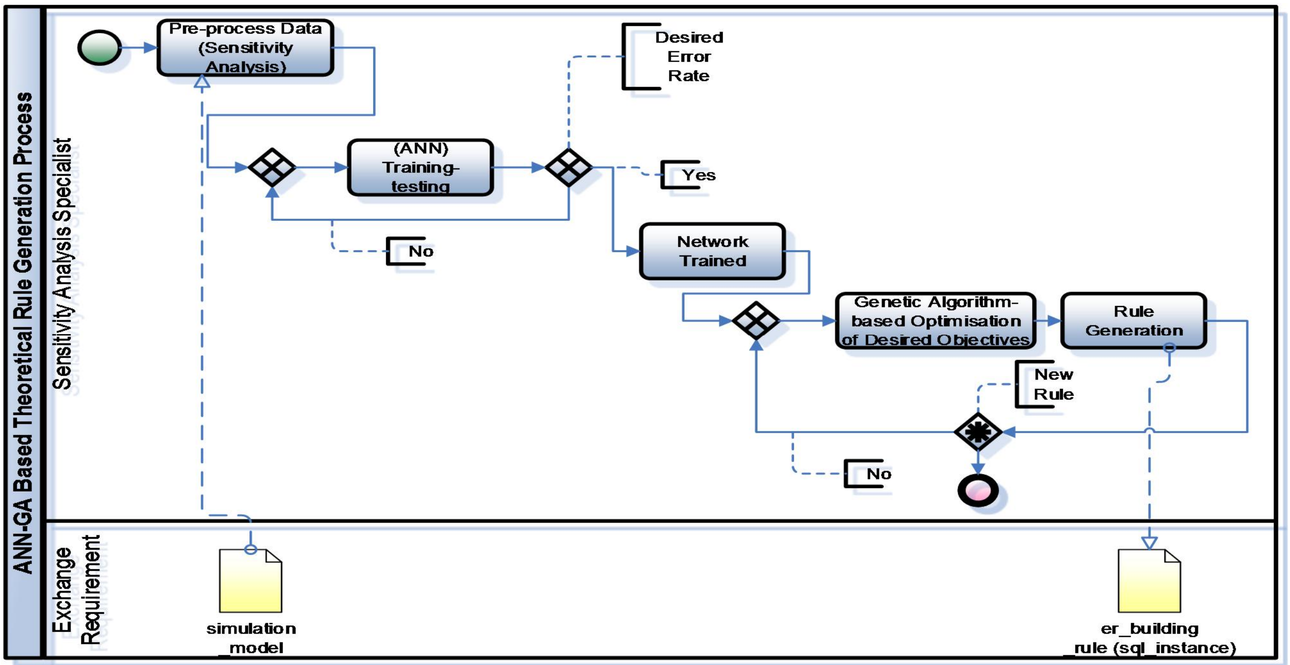

Figure 7 ANN-GA Based Theoretical Rule Generation Process: BPMN

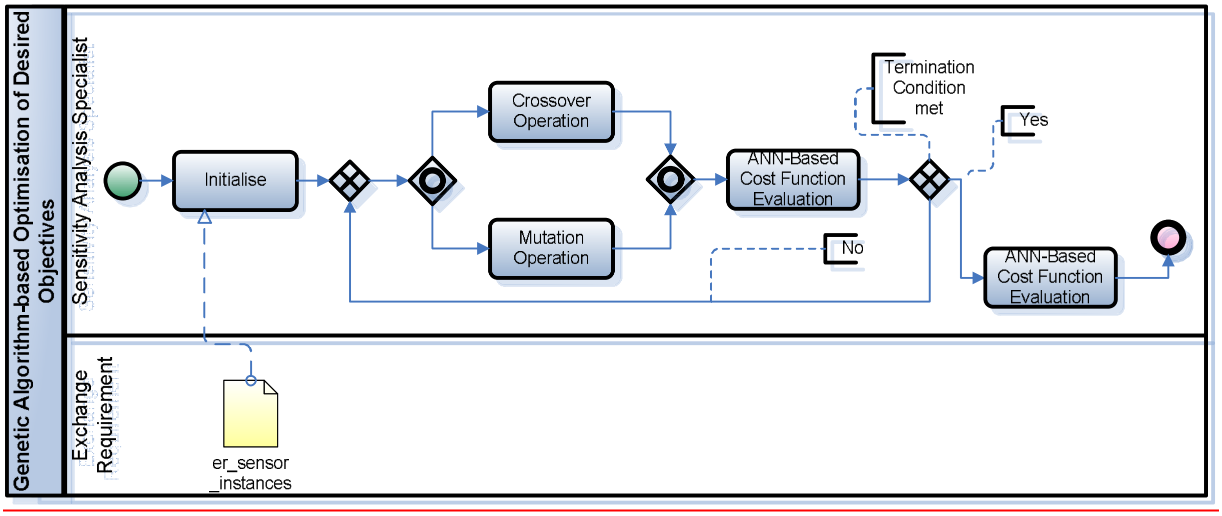

Figure 8 Genetic Algorithm-based Optimisation of Desired Objectives: **BPMN**

3.9.4 Information Requirements Inputs: Conduct Sensitivity Analysis and Develop Rules

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc	owl
Energy Simulation Model	Data Configured to meet requirements						
Data Instance Generated periodically by devices, (e.g. HVAC, sensors)	The following properties should be included					IFC does not store data instances	Zone
	Identification		String	n/a	x	"	Identification
	Description		String	n/a	x	"	Description
	Type		Enum	n/a	x	"	Type
	DateTime		String	n/a	x	"	DateTime
	DataType		String	n/a	x	"	DataType
	Unit		String	n/a	x	"	Unit
	Value		String	n/a	x	"	Value
	Zone		String	n/a	x	"	Zone

3.9.5 Information Requirements Outputs: Conduct Sensitivity Analysis and Develop Rules

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc	owl
SWRL Rules	The following properties should be included (if not known then probable values should be used):						C:SWRLRule
	Identification	Identification	String	n/a	X	IfcGloballyUniqueId	uri
	rule_id	Rule ID	String	n/a	X	IfcGloballyUniqueId	d:hasRuleID
	weight	Weight of the rule	Double	n/a	X	IfcValue	d:hasWeight
	efficiency_target	Class of efficiency (10%, 20%, 30%)	Double	n/a	X	IfcValue	d:hasEfficiency_target
	rule_type	PMV, Total Heat Reduction, Electricity Reduction, Total Cooling Reduction	String	n/a	X	IfcLabel	d:hasRuleType
	suggestion	Related suggestion as optimization action	String	n/a	X	IfcLabel	d:hasSuggestion
	zone_id	Related zone of the building	String	n/a	X	IfcGloballyUniqueId	c:Zone

3.10 Sub-process: Data Mining and Rule Generation

3.10.1 Overview: Data Mining and Rule Generation

This process is concerned with first collecting and aggregating all available metered data (weather, energy, indoor sensors and user activity data). Once this is complete, data mining can begin. This results in a collection of SWRL rules. More information in reference to the semantic rules is depicted on the deliverable D2.2.

3.10.2 Actor(s): Data Mining and Rule Generation

Actor(s)	Description
Data Mining and Rule Generation Expert	Generates rules from all available data and outputs as SWRL rules (r-box)

3.10.3 BPMN: Data Mining and Rule Generation

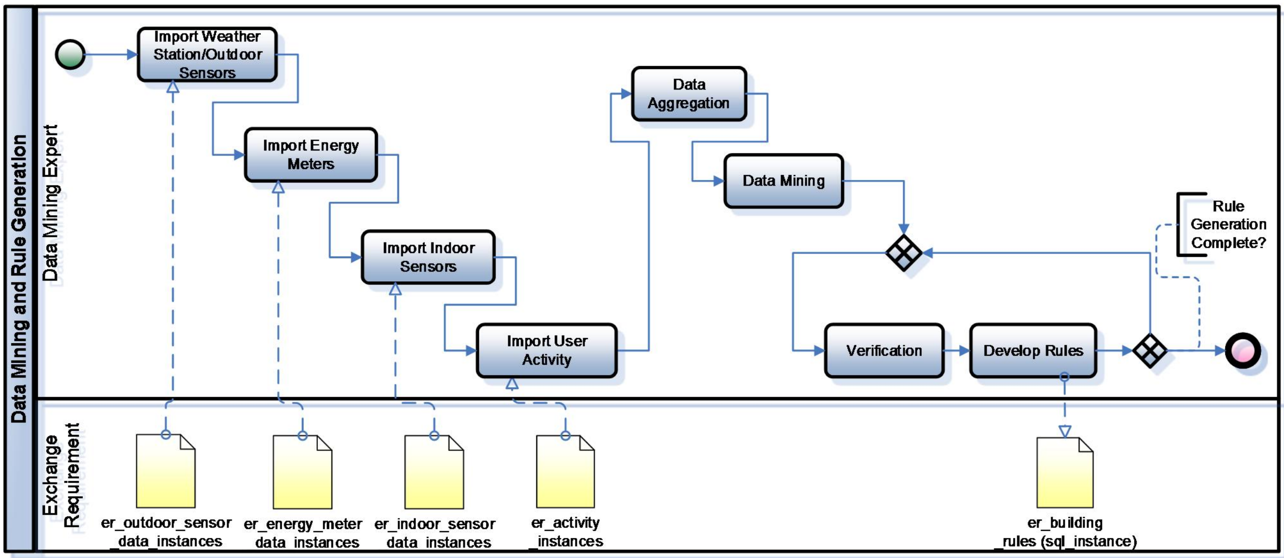

Figure 9 Data Mining and Rule Generation: BPMN

3.10.4 Information Requirements Inputs: Data Mining and Rule Generation

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc	owl
Data Instance Generated periodically by devices, (e.g. HVAC, sensors)	The following properties should be included						Zone
	Identification		String	n/a	x		
	Description		String	n/a	x		
	Type		Enum	n/a	x		
	DateTime		String	n/a	x		
	DataType		String	n/a	x		
	Unit		String	n/a	X		
	Value		String	n/a	X		
	hasZone		String	n/a	x		

3.10.5 Information Requirements Outputs: Data Mining and Rule Generation

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc	owl
SWRL Rules	The following properties should be included (if not known then probable values should be used):						
	Identification		String	n/a	x	IfcGloballyUniqueId	
	rule_id	Identification	String	n/a	x	IfcGloballyUniqueId	
	Weight		Enum	n/a	x	IfcValue	d:hasWeight
	Efficiency Target		String	n/a	x	IfcValue	d:hasEfficiencyTarget
	Rule Type		String	n/a	x	IfcLabel	d:hasRuleType
	Suggestion		String	n/a	x	IfcLabel	d:hasSuggestion
	hasZone		String	n/a	x	IfcGloballyUniqueId	c:Zone

3.11 Sub-process: Integrate Rules with RT-Controller

3.11.1 Overview: Integrate Rules with RT-Controller

The reasoning process is based on several operations that take into account the execution of the available SWRL rules by two different engines (JESS Engine and Fuzzy Rule Engine). In particular (for more information on the technical implementation, see Deliverable D3.2):

- Step 1 – The Reasoning module (Reasoning Service) retrieves the updated KB (OWL Data) and rules (in SWRL format from the Rule Base) and then translates (by using the JESS Rule Engine Bridge) this information in the format supported by the JESS Engine (JESS Facts and JESS Rules), namely: a) concept and role instances of ABox are translated into JESS Facts, and b) SWRL rules are converted into JESS Rules (Atoms mapping).
- Step 2 a – The JESS Engine is executed by using the forward chaining algorithm. The results of the inference process (new facts) are retrieved and the fired rules (executed) are identified. These results in terms of satisfied rules (fired rules) are sent to the Fuzzy Rule Engine.
- Step 2 b – The fuzzy reasoning process is performed by the Fuzzy Rule Engine. This module uses as inputs the fired rules of the previous step (identified by the JESS Engine) in order to retrieve their fuzzified version (with weights) from the Rule Base (since each rule has an ID). When the rules (f-SWRL) are available the fuzzy reasoning is performed and, at the end, for each executed rule a corresponding optimization action is identified.
- Step 3 – The optimization actions (identified in the previous step) are stored in the local database of the RT Controller and made available to the GUI application through a set of RESTful Web Services.

3.11.2 Actor(s): Integrate Rules with RT-Controller

Actor	Description
RT-Controller Expert	Extracts required data from available resources and populates ontology with assertions (a-box). Supervises the reasoning services evaluating the rules fired (in terms of action suggestions stored in the local database).
Data Mining Expert	Supervises the data mining process devoted to the generation of the SWRL rules managed by the RT-Controller.

3.11.3 BPMN: Integrate Rules with RT-Controller

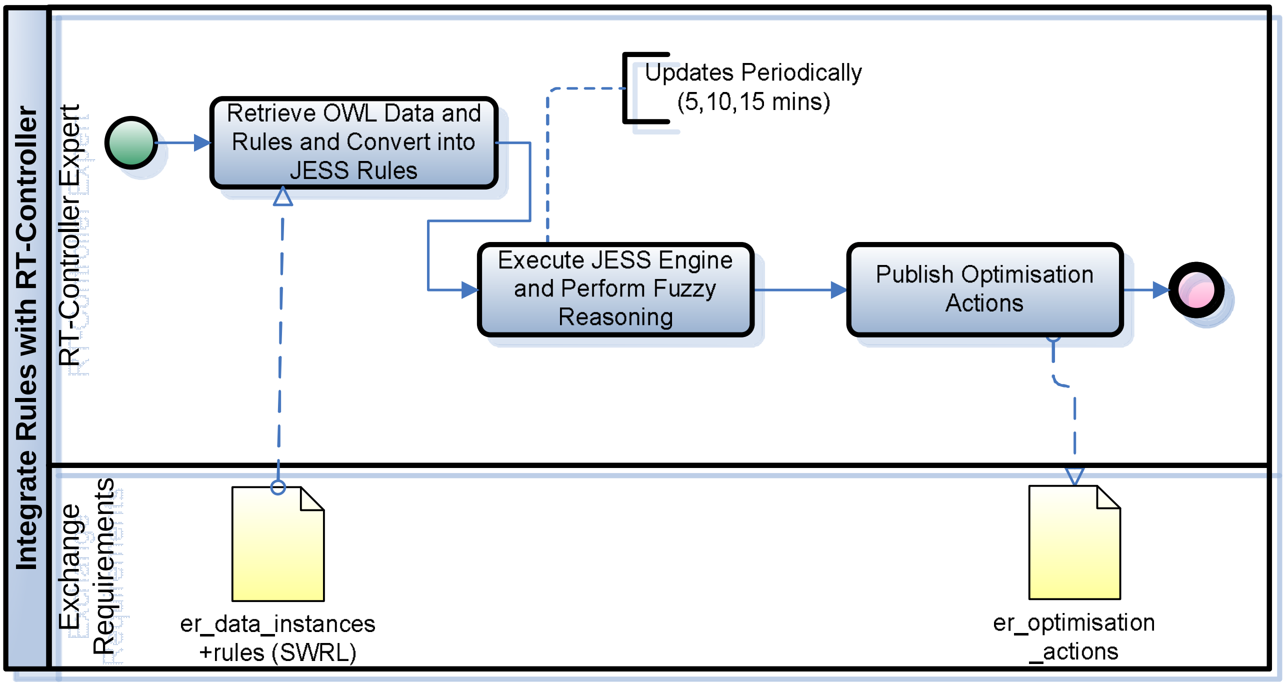

Figure 10 Integrate Rules with RT Controller: BPMN

3.11.4 Information Requirements Inputs: Integrate Rule with RT-Controller

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc	owl
SWRL Rules	The following properties should be included					IFC does not store data instances	Zone
	Identification		String	n/a	x	“	Identification
	Description		String	n/a	x	“	Description
	Type		Enum	n/a	x	“	Type
	DateTime		String	n/a	x	“	DateTime
	DataType		String	n/a	x	“	DataType
	Unit		String	n/a	x	“	Unit
	Value		String	n/a	x	“	Value

3.11.5 Information Requirements Outputs: Integrate Rule with RT-Controller

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	ifc	owl
Recommendations	The following properties should be included						c:Recommendation
	Identification		String	n/a	x	IfcGloballyUniqueId	uri
	Description		String	n/a	x		c:Description
	Rule ID		String	n/a	x	IfcGloballyUniqueId	has:RuleID
	Weight		Enum	n/a	x	IfcValue	d:hasWeight
	Efficiency Target		String	n/a	x	IfcValue	d:hasEfficiencyTarget
	Rule Type		String	n/a	x	IfcLabel	d:hasRuleType
	Suggestion		String	n/a	x	IfcLabel	d:hasSuggestion
	hasZone		String	n/a	x	IfcGloballyUniqueId	c:Zone

3.12 Sub-process: Building Monitoring and Control

3.12.1 Overview: Building Monitoring and Control

The building monitoring and control process is twofold. Firstly, the visualisation expert must integrate all required data sources so that they may be displayed to the Facility Manager (FM) so as to support them in making informed decisions about how to reduce energy consumption and improve energy efficiency in the building. The FM achieves this by consulting the interface and monitoring current, historical and future energy consumption and consulting the RT controller's actuation suggestion on a zone by zone basis. One the FM is suitably happy with a suggestion; they must then configure the building to align with the given suggestion. For example, the FM may be informed by the suggestion to adjust heating/cooling set points, blind heights, lighting levels, etc. For more information on this process consult deliverables D4.2 and D4.3.

3.12.2 Actor(s): Building Monitoring and Control

Actor	Description
Visualisation Expert	**Integrates All Required Data Sources into Visualisation Interface.**
Facility Manager	**Monitors Zones and Responds to Recommendations from RT Controller.**

3.12.3 BPMN: Building Monitoring and Control

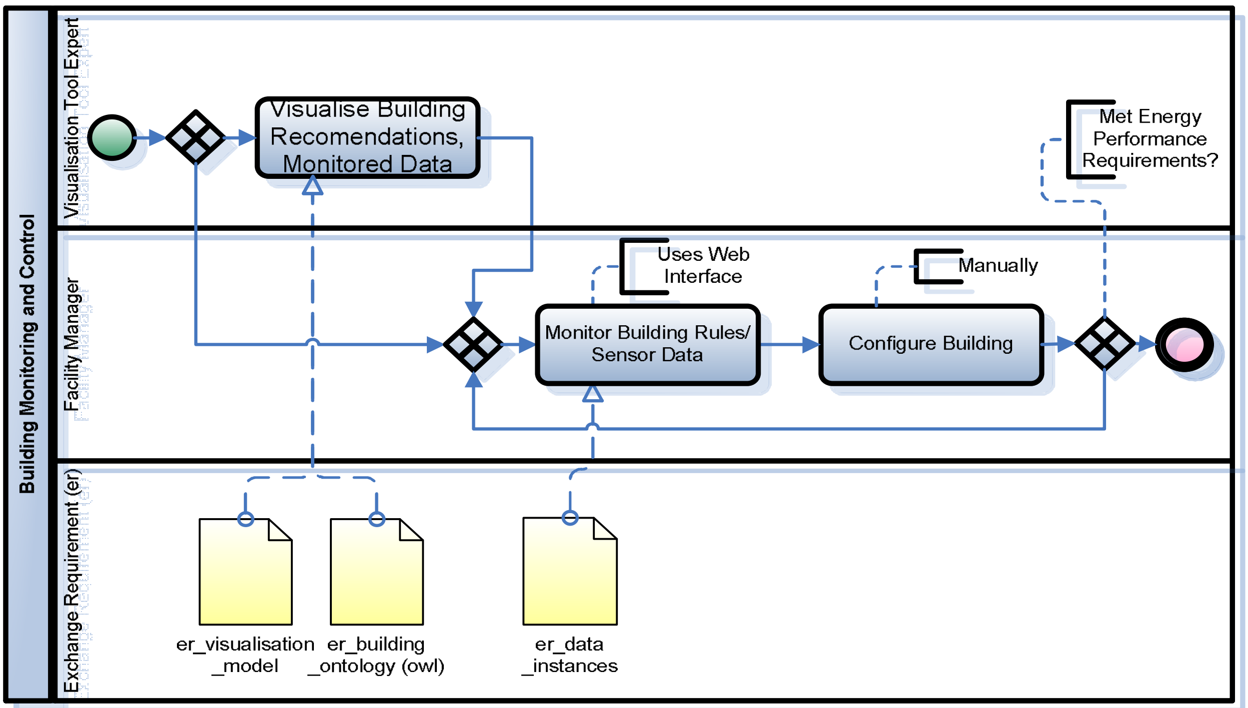

Figure 11 Building Monitoring and Control BPMN

3.12.4 Information Requirements Inputs: Building Monitoring and Control

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	Ifc 2x3	owl:knoholem
Building	The following properties should be included:					IfcBuilding	c:Building
	Identification		String		x	IfcGloballyUniqueId	uri
	2D Geometry	line	points		x	IfcRepresentation	c:Line
Building Stories	The following properties should be included:					IfcBuildingStorey	c:BuildingStorey
	Identification		String	n/a	X	IfcGloballyUniqueId	uri
	Elevation	Relative to building datum	Real	m	X	IfcLengthMeasure	o
Structural Element In addition to those provided within the geometry model)	The following properties should be included					IfcBuildingElement	c:StructuralElement
	Identification					IfcGloballyUniqueId	uri
	Description						c:Description
	Type					IfcLabel	d:hasType
	Placement					IfcPlacement	c:Placement
	Geometric Properties	(length, width)				IfcRepresentation	c:Representation
Sensors	The following properties should be included					IfcSensorType	c:Sensor
	Identification		String	n/a	x	IfcGloballyUniqueId	uri
	Description		String	n/a	x		c:Description
	Device Type		Enum	n/a	x	IfcLabel	d:hasType
	Placement		String	n/a	x	IfcPlacement	c:Placement
	Measurement Unit		String			IfcUnit	d:hasMeasurementUnit
Recommendations	The following properties should be included						c:Recommendation
	Identification		String	n/a	x	IfcGloballyUniqueId	uri
	Description		String	n/a	x		c:Description
	Weight		Enum	n/a	x	IfcValue	d:hasWeight
	Efficiency Target		String	n/a	x	IfcValue	d:hasEfficiencyTarget
	Rule Type		String	n/a	x	IfcLabel	d:hasRuleType
	Suggestion		String	n/a	x	IfcLabel	d:hasSuggestion

Type of Information	Information Needed	Additional Notes	Data Type	Units	Required	Ifc 2x3	owl:knoholem
	hasZone		String	n/a	x		c:Zone
Data Instance Generated periodically by devices, (e.g. HVAC, sensors)	The following properties should be included						
	Identification		String	n/a	x	IfcGloballyUniqueId	uri
	Description		String	n/a	x		
	Type		Enum	n/a	x	IfcLabel	d:hasType
	DateTime		String	n/a	x	IfcDateAndTime	d:hasDateTime
	Unit		String	n/a	X	IfcUnit	d:hasUnit
	Value		String	n/a	X	IfcMeasureValue	d:hasValue
	hasZone		String	n/a	x		c:Zone
Zones	The following properties should be included (if not known then probable values should be used):						Zone
	Identification		String	n/a	x	IfcGloballyUniqueId	uri
	Description		String	n/a	x		d:hasDescription
	Zone Type		Enum	n/a	x	IfcLabel	d:hasType
	Zone Symbolic Name		String	n/a	x	IfcLabel	d:hasSymbolicName
	Zone Placement		String	n/a	x	IfcPlacement	c:Placement
	Zone Perimeters	If zone is non rectangular	String	n/a		IfcRepresentation	d:hasPerimeters

4 CONCLUSION

This document provides a set of use cases developed to meet the requirements of the KnoHolEM solution. By taking the formalised approach of using the Information Delivery Manual, the use cases are captured in a manner which promotes dissemination beyond the project, and also ties the data models and suggested IFC entities into a process required for certification within the IFC standard, as described by BuildingSmart.

5 BIBLIOGRAPHY

[1] C. Eastman, Y. S. Jeong, R. Sacks, and I. Kaner, "Exchange model and exchange object concepts for implementation of national BIM standards," *J. Comput. Civ. Eng.*, vol. 24, no. February, p. 25, 2010.

[2] W. M. Liebich Thomas , Stuhlmacher Konrad and S. R. J. Guruz Romy, Katranuschkov Peter, "Information Delivery Manual Work within HESMOS," 2013. [Online]. Available: http://hesmos.eu/downloads/hesmos_additional-del_idm_final.pdf. [Accessed: 11-Aug-2014].

[3] O. M. G. D. Number, "Business Process Model and Notation (BPMN)," no. January, 2009.

[4] M. Fowler, *UML distilled: a brief guide to the standard object modeling language*. Addison-Wesley Longman Publishing Co., Inc. Boston, MA, USA, 2003.

[5] B. Yuce, Y. Rezgui, and S. K. Howell, "ANN-Genetic Algorithm-Based Rule Generation for Holistic Energy Management in Public Buildings," in *10th European Conference on Product & Process Modelling*.