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Interoperable tools for designing energy-efficient buildings in healthcare districts

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ABSTRACT: The EU funded collaborative research project STREAMER aims on Energy-efficient Buildings (EeB), focusing on mixed-use healthcare districts. Besides innovations in EeB technology, special emphasis is laid on improving methodologies and tools used in the design process of new or retrofitted hospital buildings. STREAMER follows a model-based, holistic approach by integrating design data on both building and district level. Advanced ICT methods like Semantic Web, Ontologies, Parametric Modelling or Knowledge Based Systems, will be reviewed, adapted, and improved to use them during the energy-efficient-buildings design process. The project not only aims on developing theoretical concepts, but also on practical case studies: based on already existing software, a number of interoperable software tools shall be developed and evaluated in four demonstration projects. The paper describes the system architecture and provides a functional spectrum of the design tools, focusing on interoperability issues.

1 INTRODUCTION

The European Union (EU) is working hardly and dedicating many of its resources on climate protection. To achieve its goals, investments in energy efficient buildings (EeB) are very important. Furthermore, it is not sufficient to concentrate only on the building itself, but also on the integration of the building in its neighbourhood, especially taking into account available energy supply systems, which is of equal importance. It is necessary to take into account the aspects of energy efficiency and the influence of the design phase of new buildings as well as during retrofitting existing buildings.

The main goal of the EU collaborative project STREAMER (Sebastian 2013) is to develop improved design methodologies for energy-efficient healthcare districts. Furthermore, functional prototypes of design and simulation tools shall be developed, enabling to test and evaluate the new methodologies by real design projects in different hospital areas all over Europe. The application area of healthcare districts was chosen since, compared to other buildings types, hospital buildings have a significantly higher energy demand and CO₂ emission.

To tackle this multi-dimensional complexity of this problem, a holistic approach has been chosen: i.e., not only it takes into account the technological aspects of an energy-efficient design, but also the neighbourhood infrastructure, the hospital users (patients, staff, and visitors), and the hospital functional

aspects. The tools developed in the project need to support the following:

- the optimisation of the building envelope within the given neighbourhood,
- the optimisation of the room-layout within the building envelope, and
- the optimisation of technical equipment on building and room level.

To solve this multi-criteria optimisation problem, efficient assessment and simulation tools are needed. Besides energy-efficiency, operational and financial aspects have to be regarded as Key Performance Indicators (KPIs) for an optimal design.

Design methodologies and tools shall be used in all phases of the design process and need to support the construction of new buildings as well as the retrofitting of existing ones. A central component is the Product Data Model (PDM), which is accessible by all tools used in the design process. Later on, this PDM shall also be used as a basis for an efficient building operation. The PDM incorporates a Building Information Model (BIM) of the new or retrofitted hospital building and model data of the building neighbourhood (existing buildings in the healthcare district, energy supply systems on district level, streets, parking areas, etc.) provided by Geospatial Information Systems (GIS).

The structure and the information content of the BIM data changes during the design process: i.e., in early stages, “requirement models” without a concrete geometrical representation of the building en-

velope or the rooms, or geometrically rough, parametric building and room models will be available. Later, with the progress of the design process, the rough early design models are refined with standard CAD modelling tools. Since these tools cannot directly import parametric models from their current formats, these parametric models have to be transformed into an Industry Foundation Class (IFC) representation (IFC 2013).

The previous case shows that the design and simulation tools used in the STREAMER context need to access, evaluate and integrate data in different representations, which causes a lot of interoperability issues. This paper focuses on discussing the STREAMER approaches for solving these interoperability issues.

Section 2 briefly describes the different software tools envisaged to be developed or used in STREAMER, concentrating on the intended functionality and the supported data models. Section 3, which is the core of the paper, is devoted to interoperability of the different tools, where the overall system architecture is illustrated, and a number of approaches to integrate model data in different formats or to transform them from one format into another are discussed. Finally, section 4 provides a short overview on the intended testing and evaluation of the design tools.

2 STREAMER DESIGN TOOLS

This section shortly introduces the various design tools developed or used in STREAMER. It has to be kept in mind that the project is still in its initial phase, i.e., in most cases the functional spectrum of the systems is not yet completely defined, and the implementation of the different systems has not yet started.

2.1 Functional Requirements Configurator

The Functional Requirements Configurator (FRC) allows specifying the requirements that should be fulfilled by the planned hospital building, and to formalise these requirements in a requirement model. For the corresponding data model, a specific view of the IFC standard will be developed. The requirements are mainly specified on building level, preferably by providing numbers and types of needed rooms (e.g. number of patients' rooms, operation theatres, and social rooms). Supported by a knowledge base containing specialised design rules for hospital buildings, the FRC translates the global specifications into a detailed requirement profile for each room. Afterwards, the design team may check, and eventually modify, the automatically generated requirement profiles. After finishing the specification, the corresponding IFC model is automatically

generated. Using the IFC Model View Definitions (MVD) technology, the requirement model can now be checked on completeness, plausibility or the maintaining of limits.

2.2 Parametric Design Solution Configurator

The main function of the Parametric Design Solutions Configurator (PDC) is to support generation and assessment of rough "early design" models of the planned building. In order to keep as much as possible degrees of freedom for energetic and operational optimisation, parametric building models are used in the early design phase. The technological basis that will be used for this type of models include the Semantic Web based Concept Modelling Ontology (W3C 2009), using Ontology Web Language (OWL) (W3C 2012). STREAMER will focus on evaluating the benefits of the semantic web approach on the BIM area.

Primary basis for generating a parametric design is the requirement model provided by the FRC. Every model generated in the design process is checked regarding the specified requirements. The requirements are represented using OWL in order to facilitate the compliance checking using existing semantic web reasoning techniques and to keep the specified requirements for later phases of the design process. However, during the early design phase, it is not sufficient for a design model to only fulfil the functional requirements. In almost every use case, the building will be constructed in an existing neighbourhood, limiting position and size of a new building, providing necessary infrastructure (access roads, parking area, energy supply), or influencing the energetic situation of the building by shadowing. This kind of information, which is normally available in GIS data formats like CityGML (Gröger et al. 2012), will be included in the design process via the PDC.

The complete functional spectrum of the PDC is still under discussion. The tool will surely produce design alternatives in a semi-automatic manner. It is intended that the software automatically generates design solutions supported by an expert system with specific design rules. Furthermore, the proposed design models are visualised and assessed with respect to energy efficiency and other KPIs. The user can, to a certain extent, control the automatic generation of parametric design models, and he or she shall be able to manually modify the proposed models. The generation of detailed design models is outside the scope of the PDC. Instead of this, parametric models at any time can be transformed into IFC, enabling a further detailing of the design with standard CAD tools. It has not been decided yet whether the PDC will also provide functionality for checking or assessing detailed design models.

2.3 Energy Simulation System

Energy assessment tools are required at different stages of the design process to estimate and validate early-design options or to analyse the energy performance of more detailed configurations. Moreover, different scales should be covered, more precisely at building level or at neighbourhood scale.

Therefore, a set of relevant energy assessment tools should be selected and integrated into the STREAMER platform to cover the whole design process at both building and neighbourhood scales. In the early stage, the selected tools will rely on simplified building models integrated in global district energy models (including energy network models) to estimate the performance at neighbourhood level. In the next stage, advanced energy calculation can be done. Then, the capability of the tools to work with BIM formats (and quite specially the standard IFC format) will be an important selection criterion, as well as their ability for modelling MEP equipment (e.g. HVAC) with appropriate parameters. Several energy simulation software tools are candidates, like Energy plus, TRNSYS, IES VE, TAS, ESP-r, to mention a few.

Within STREAMER the focus is on energy use in the context of both BIM / building level and GIS / district level. For the optimisation of energy use it is important to understand the requirements for energy use in each moment. The expectation is that the total sum of maximum needed energy per subpart is higher than the maximum needed energy use of the total part at any time of a day. This is due to the fact that maximum needed energy per sub part is only required for a certain part of the day. Within a building or even a complete hospital area, the moments of required energy use are partially distributed.

In a total hospital area the different needs for energy are supported typically by more than one source. This creates an interesting network of sources and sinks for energy with different values at each time of the day. Looking at GIS / district level it is also interesting to simulate the sources and sinks for energy generation and energy use over time. To enable this, Energy Simulation Systems are needed.

The problem is even more interesting when parts of some systems need to be covered by more than one network. Integrating BIM in this GIS problem/question enables integrating more detailed building information in the basic information for the sources and sinks. This also enables comparing alternatives and influences on the total energy house hold given by investing in better materials, like triple glazing windows for example. This is not only true for the materials but also for the building layout, room type selection etc.

2.4 Design Solution Support System

The main goal of STREAMER is to develop design methodologies for energy efficient hospital buildings. Unfortunately, energy efficiency is not the only performance indicator, i.e., it is necessary to develop a design which is accepted by all relevant actors (stakeholders, hospital staff and patients). This is why additional Key Performance Indicators (KPIs) have to be taken into account.

KPIs can roughly be classified into quantitative and qualitative parameters. Besides energy efficiency, the energy demand of the total building lifecycle, the efficiency of the hospital operation and the costs are important quantitative parameters. A special challenge for STREAMER will be to tackle also qualitative KPIs like safety or patients and staff comfort requirements.

The Design Solutions Support System is envisaged to support the design team in assessing different KPIs in order to find acceptable trade-off between conflicting design goals.

2.5 Standard CAD/GIS modelling Tools

The intention of STREAMER is not to develop new BIM tools or new geographic information systems, but to use and integrate existing applications as far as possible. This is why besides the necessary functionality of the applications, their capability to support open and standardized data models will be of special interest.

For STREAMER, it is not sufficient to only support open standards. The import and export of partial models and the support of model views must be possible. This should ensure that in every project phase all the required information is available, and that the collaborative processes are possible.

In the area of geospatial data, spatial data bases and standardised web services are well established. Examples for web services standardised by the Open Geospatial Consortium (OGC) are the Web Map Service (WMS 2006), the Web Feature Service (WFS 2010) and the Sensor Observation Service (SOS 2012). As more and more public data (e.g. INSPIRE 2014) can be accessed via web services, STREAMER will rely on web services in commercial application as well as the newly developed software prototypes.

3 INTEROPERABILITY OF DESIGN TOOLS

For an efficient support of the design process, the different tools mentioned in section 2 have to be integrated into an overall system. In the system architecture favoured in the STREAMER project (see Fig. 1), the cooperation of the different components is organised by a model-based Product Lifecycle Management (PLM) system (see section 3.1). A

main component of the PLM system is a database for storing and retrieving various kinds of information, i.e. documents, requirement models, design models or geographical information on district level. The different design tools communicate with the PLM system via suited web services.

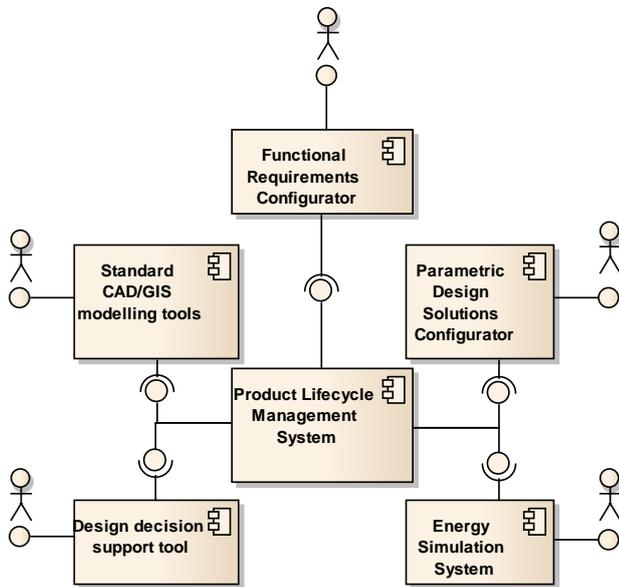


Figure 1: STREAMER system architecture

A special challenge for STREAMER is that the system has to deal with various kinds of information represented in different data models. On the one hand, for an optimized design, data from the two application domains BIM and GIS have to be integrated. Furthermore, in the BIM area different data models are used.

In the earlier phases of the design process, it makes sense to concentrate on a formal representation of functional requirements for the new or retrofitted hospital building. In the later phases, early design models that fulfil the specified requirements are created and assessed for energy efficiency. In these phases of the design process, parametric BIM based on ontologies shall be used. The early-design models have to be refined and enhanced in later phases of the process. Actually, this can only be performed with standard CAD-systems, requiring different representations of the building data.

Thus, for ensuring the interoperability of the different design tools, a number of principal problems need to be solved. For some tools like, the energy simulator, specialised interfaces supporting specific BIM representations have to be developed (see section 3.4). In case the integration of a specific interface is not possible, BIM data have to be transformed from one representation into another without information losing during the transformation (see section 3.3).

An additional principal interoperability issue is the integration of BIM and GIS based model data (see section 3.2). For this purpose, there are different approaches, which shall be studied in STREAMER:

the definition of a universal data model, the transformation of the BIM data into a GIS format, and the direct integration of BIM and GIS data on tool level.

3.1 PLM-System

Applying BIM on the overall design, construction, and exploitation process is an interesting, but only partial solution. Indeed, the use of BIM raises several questions since the ownership and control of information becomes unclear when this information is put together in a unique model, accessed by all stakeholders. Therefore, it seems of paramount importance to couple BIM with tools allowing to capture and to support the organizational and the workflow processes. This is the purpose of PLM tools. Based on a recent definition from CIMData (PLM 2014), PLM “is the process of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal”; PLM integrates people, data, processes and business systems and provides a product information backbone for companies and extended enterprise.

The interesting features of PLM solutions are related to:

- Tracking of design changes: due to the iterative nature of design, various versions of documents emerge and it is necessary to assure that the proper versions are used. In doing so, PLM solutions ease the sharing of information and also improve the quality of the design.
- Defining read/write rights on the documents: during the different stages of the process, different stakeholders need to access a specific part of the project information either to just consult it or to modify it. PLM solutions allow defining, in a very formal way, these communication rights in order to give writing permissions for every stakeholder on the part of the information for which he or she is responsible for, and the read-only permissions for the other parts of the information needed for his or her tasks.

The on-going research aims at bridging the gap between the BIM world and the PLM world, and then at applying these interesting features of PLM solutions to BIM. We consider that each part of BIM needs to be linked to a specific stakeholder that becomes the IP owner and releaser in order to maintain the information ownership and responsibility. The approval process can also be described and hence allowing to track changes and to retrieve the proper version of the design. This will enforce the quality of the communications and allow a better response to clients’ requirements.

3.2 Integration of BIM and GIS data

Today, two main application domains are applied in the area of districts. On one hand, the Building Information Modelling (BIM) with highly detailed information of buildings and building aggregations, and on the other hand, the Geographic Information Systems (GIS) with the focus on any geospatial information on different scales. Within their domains, both modelling methods are well adapted and standardized by international organizations (Fig. 2).

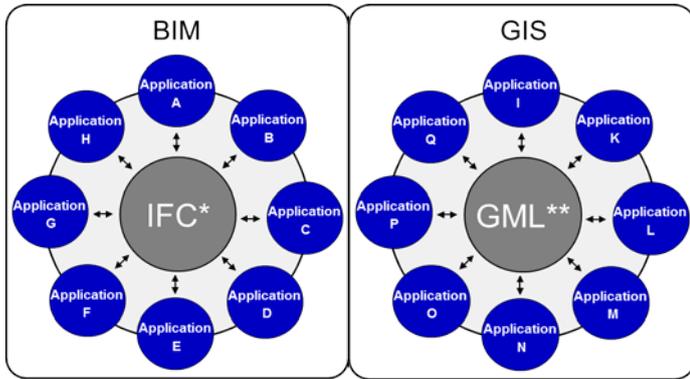


Figure 2: Interoperability within the domains BIM and GIS (* IFC, gbXML; **GML application schemas, e.g. CityGML)

Besides being applied in different application domains, both modelling methods are also based on different technologies. In the area of Building Information Modelling, IFC is a standardised (IFC4 - ISO 16739) and a well-accepted semantic data model for detailed buildings. Although there is an XML (Extensible Markup Language) representation of IFC, the most frequently supported version of IFC is the STEP Physical File (ISO 10303-21). The IFC model is based on STEP (Standard for the Exchange of Product Model Data) and modelled in EXPRESS. On the other hand, geospatial modelling is dominated by GML (Geography Markup Language) and corresponding application schemata. Conceptual GIS models are based on UML and encoded by XML schemata.

Especially as a link between BIM and engineering analysis tools (e.g. energy, lighting), the Green Building XML (gbXML) has become a de facto industry standard (gbXML 2014). gbXML is based on XML and allows to model both districts and single buildings. The model contains building information as well as weather information and cost aspects.

As already mentioned in the introduction, STREAMER is not only focusing on detailed modelling of hospital buildings, but also on the complete hospital district. This means that highly detailed and less detailed buildings are used simultaneously. Sources for the latter type of information may be cadastral data bases or specialised (internal or public) geospatial information systems providing infrastructure data on district level.

In order to achieve a holistic assessment of the complete hospital district, all relevant information

from these different levels and domains have to be combined. This integration of information across different domains can be achieved in different ways:

- By defining an universal data model which covers all aspects of all involved domains,
- by applying ETL technique (Extract, Transform, and Load) on the information to convert it from one domain into another, or
- by integration on application level.

In order to integrate building models from the BIM domain (represented in IFC) and building models from the GIS domain (modelled in CityGML), a “Unified Building Model” has been proposed. This model encapsulates the CityGML and the IFC model. It is claimed that a translation between the models is avoided and therefore no loss of information occurs (El-Mekawy et al. 2012). But this approach is restricted to the IFC and CityGML standards. Other building models like gbXML and other geospatial data formats are not taken into account.

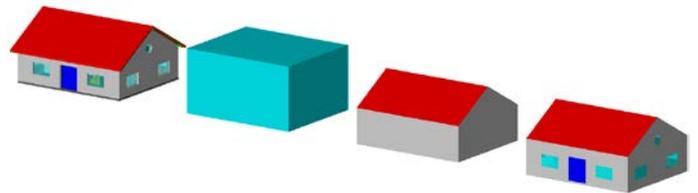


Figure 3: Model conversion: original IFC model (left) and converted CityGML model LoD1, LoD2, LoD3 (source: KIT)

If data models are extensible, missing entities or features can be modelled as a domain extension. CityGML has such an Application Domain Extension (ADE) mechanism, which allows defining new features and properties. One example for such an extension is the GeoBIM ADE (de Laat & van Berlo 2011), which provides some aspects of a BIM-GIS universal model. However, as CityGML is an application schema of GML, the domain extensions should be compatible to GML. This means that the GML geometry types have to be used, which severely restricts the possible geometric representations. Constructive Solid Geometry (CSG) and parametric geometry, which are frequently used in the BIM area, are not supported by GML.

One modelling approach, which claims not to be domain-specific is the semantic web technology (W3C 2014). It allows data to be shared across specific domains by allowing machines to “understand” semantically structured information. The OWL format is a technology used to describe Knowledge Bases. It allows defining classes and their properties, relations between classes, cardinalities, equality and characteristics of properties. Semantic reasoners may then infer logical consequences from these facts described by OWL and several axioms.

The second alternative to integrate data from different domains is based on the selection of the most appropriate domain and converts the data from other domains into this domain. For this, normally a se-

semantic and geometric transformation is necessary, and possibly resulting in loss of information. If the data models follow different modelling concepts, the transformation process can be difficult. For example IFC is mainly based on modelling building elements as objects with solid geometry, while CityGML is mainly based on representing the visible surfaces of building elements (boundary surfaces) with surface geometry. Extracting the relevant boundary surfaces from IFC objects with solid geometry is principally possible (cf. Fig. 3). Rebuilding an IFC model from boundary surfaces is much more difficult, especially if the solid geometry needs to be compliant with the IFC Coordination View (IFC-CV2.0).

The third alternative is the data integration on application level. This has the advantage that existing data models and especially existing instance documents can be used directly. However, in this case, the application has to deal with different technologies and data formats. The IFCEXplorer (Benner et al. 2013) is a prototype application for integrating IFC, GML based application schemas, geographic raster information like OpenStreetMap (Ramm 2010) or WMS maps and non-semantic data like point clouds and polygon meshes. All data are presented in its original context (Benner et al. 2010). Fig. 4 shows the integration of an existing building modelled in CityGML and a part of the newly planned extension as IFC building model

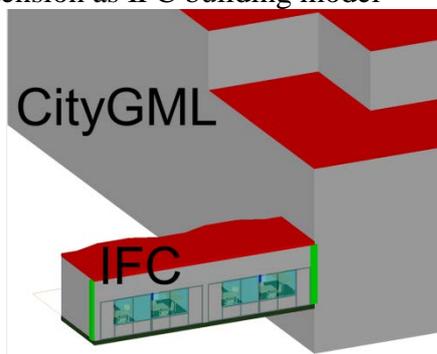


Figure 4: Geospatial and BIM data in one application: the existing building (CityGML) and part of the newly planned extension (IFC) (Source: KIT, De Jong Gortemaker Algra)

The used IFC version 2x3 only allows a geodetic coordinate reference system to position the model in the real world. The CityGML model is based on cadastral data from the Dutch coordinate reference system (EPSG:28992). Therefore, a coordinate transformation is needed to integrate the data correctly.

As mentioned above the IFCEXplorer is integrating different data models in one document. At the moment all the data are accessible on application level with their specific characteristics, e.g., entity/feature name, properties and relations. Further evaluations and data processing have not been performed so far. In a first step, it is planned to establish spatial relation between the integrated data models. More relations between the models will be created if necessary.

In the project STREAMER, it is not intended to store the integrated models in a common format. In fact, the source of each model (file location, data base, web service), the relations between the models, and the processing results, if available, will be stored.

3.3 Transformation between IFC and Ontology-based representations

With the Parametric Modelling Ontology, we describe a specific extension of the Conceptual Modelling Ontology (CMO) (CMO 2014) that works as a layer on top of OWL in the Semantic Web area. This standard is coming from existing EU projects (SWOP, ManuBuild, Proficient). Next to that, Semantic Web in general is a promising technology from the standardisation body W3C. As IFC is widely supported in commercial applications, and several of the issues and limitations identified in IFC (Pauwels 2011) seem to be solvable in the area of Semantic Web, many parties are looking to create a conversion from IFC towards Semantic Web.

Most researchers focus on a conversion on the technology level independently from the classes within the IFC schema. Usually, this conversion does not generate the perfect result. For instance, the distinction between types and instances is defined as a relation between two entities in IFC, whereas within the Semantic Web, instances and types are intrinsic by definition. Whatever generic conversion is chosen, the type/instance relation being an intrinsic property of OWL in Semantic Web is not assigned correctly. The reason why this is still a preferred way for many conversions is at least three fold:

- A conversion on technology level is directly adaptable for all STEP/EXPRESS based standards, not only different versions from IFC, but also AP214 and other standards.
- Only in case of a conversion on technology level, the result can really be called “ifcOWL”.
- It is cleaner from data modelling point of view to keep conversion clear and without interpretation.

All these arguments are valid. Next to that, typically within a Semantic Web environment, it is possible to convert the resulting ifcOWL ontologies towards new representations. These conversion possibilities within the Semantic Web domain are very rich, however looking at the complexity of geometry representations and complexity in conversions, it seems that it is not feasible to do this without coding.

Within STREAMER the initial choice is to look at CMO with extensions that has its own geometry ontology on top of OWL. This geometry ontology is constructed in a way that it fits the Semantic Web: there is a conversion from IFC towards this ontology for the geometry contained within IFC. However this conversion is built in code, currently it seems to be too complicated to convert 1-to-1 converted IFC ge-

ometry representations in OWL with standard conversion capabilities towards new representations for the same geometry.

For the non-geometrical data within STREAMER, foreseen solutions from research institutes and universities to convert data from IFC towards the Semantic Web seem applicable. These differences from geometry as the technical structures behind are less complicated.

IFC itself stores almost no parametric information. Examples for the usage of parametric information are profile definitions. This parametric information is limited and very strictly focused on a specific representation. One exception can be found in the way Boolean operations are applied on top of geometry. For example the definition of a wall is that it is bounded by the plane where the roof is clipping the wall, also the connections and boundaries by other walls are given.

In STREAMER's definition of parametric behaviour, it is not foreseen incorporating this relational knowledge as a basis for parametric (even though they are available in Semantic Web results). Parametric information will be added 'by hand' or by template. An example of a template can be that any wall of a certain type can be defined by a parameter that defines the thickness or the height, for instance. This way, a simple house can have one type for all outer walls, and by applying the template, it could enable changing the thickness or the height of all outer walls at the same time by one parameter.

As IFC generally does not contain parametric behaviour, the conversion from a Parametric Ontology towards IFC can only convert a specific created instance. Although this loses a lot of (parametric) knowledge, the result is still relevant for applications that can apply calculations on a model like quantity take off or energy calculations.

3.4 *Semantic interface of simulation tools*

As described before, it is very relevant for STREAMER to make use of simulation tools.

The main issue of the simulation tools is that they should present the simulation results in a correct and understandable way. The results need to be user-friendly so that the people that use the tools can understand them easily. It is also important that the results can be used by other software products.

As STREAMER is an innovative project, it creates new combinations of existing and/or new software. To allow these individual products perform jointly with each other, we try to use, as much as possible, existing open standards in the area of BIM and GIS. Where content that has to be communicated is new and cannot be stored in these existing standards, we try to use Semantic Web for this knowledge, the tools and especially the simulation tools will be extended to express their results in a

semantic way and to take semantic input, where possible.

4 TESTING AND EVALUATION OF DESIGN TOOLS

The STREAMER project has set very ambitious experimental and validation targets, relying on four demonstration sites in the UK, the Netherlands (Fig. 5) Italy and France. The four sites are real healthcare districts of significant sizes – e.g. the French Hospital (“La Pitié-Salpêtrière” in Paris) features a surface area of 450000 m² with 1600 beds in medicine, surgery, acute care, and long-term care.



Figure 5: Hospital complex Rijnstate Arnhem, NL (Source: RNS)

One strength of the project is that it mixes different kinds of concerns and backgrounds – research institutes and universities on one side, contractors, engineering companies, and hospital owners on the other side, to both generate high-profile academic knowledge and results, and to ensure applicability and further exploitation of these results.

In the particular regard of interoperability, the issue for the validation activities of the project is to highlight the link between interoperability improvement and the related enhancement of ICT support and, concrete impacts on more practical aspects of interest to end users: optimisation of design, energy efficiency increase, and cost-effectiveness.

The STREAMER validation roadmap therefore heavily relies on the requirements expressed by the end users (hospital owners at first), in order to translate them into precise (and when possible quantitative) metrics, that can be linked to design activities and related tools through well-defined use cases. The aim is then to “replay” some of these use cases in dedicated design workshops, relying on the ICT innovation brought by STREAMER, and to provide evidence of the gain in terms of awareness, effectiveness, and design timescale. For instance, the connection between the semantic building models and simulation tools (section 3.4) will dramatically decrease the time required to get a feedback on

building performances, and the parametric models (section 3.3) will allow semi-automated design configuration, with better performances and less design effort as concrete results.

5 SUMMARY AND CONCLUSION

The paper presented the collaborative research project STREAMER, aimed at the development of enhanced planning methodologies and tools for energy-efficient hospital complexes. In this project, functional prototypes for some new planning tools will be developed, taking into account data models on building and district level. In the process of designing a new or retrofitted hospital, besides these new tools, also existing and commercially available systems like CAD modelling tools, Geographic Information Systems or Energy Simulation Systems are applied. A special challenge for STREAMER is to organise the interoperable exchange of model data among different software systems. The paper presented and discussed approaches for integrating BIM and GIS data, which will be evaluated during the project.

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