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Model-based Planning for a Sustainable Urban Development

Sebastian Ebertshäuser, Petra von Both

(Dipl.-Ing. Sebastian Ebertshäuser, Karlsruhe Institute of Technology, Englerstr. 7, 76131 Karlsruhe, sebastian.ebertshaeuser@kit.edu)

(Prof. Dr.-Ing. Petra von Both, Karlsruhe Institute of Technology, Englerstr. 7, 76131 Karlsruhe, petra.vonboth@kit.edu)

1 ABSTRACT

The objective of the presented project is the development of methodological and information-technical fundamentals for the realization of an integrated urban information management. The main focus is on demand-oriented development of an integrated multi-scale city model for the application context of the municipal energy efficiency, which convergently depicts all relevant objects with their semantic properties and their topologies for the representation of municipal transport and energy networks. The technical implementation of the model is effected by a prototypical model management platform with functionalities for rule-based semantic model analysis. The provision of standardized interfaces enables the integration, accompanying planning, of simulations and optimization processes.

2 INTRODUCTION

Together with climate and energy policy plans Germany has framed ambitious targets for the next decades. Yet federal measures and regulations primarily focus on accelerated extension of regenerative energy carriers and on a correlating adjustment of network infrastructure, and thereby foremost on the levels of energy production and distribution. However, significant improvements on the part of energy consumption are needed in future in order to achieve the defined objectives in the long run. Germany's building sector accounts for 43% of the cumulated energy consumption, and falls under the federal responsibility of the local authorities. Furthermore, other system relevant factors lie on that level, e.g. development of local supply infrastructure and private motorized transport, where about one third of all driven passenger-kilometers are short trips by car or in local urban transport. It thus becomes clear that cities and municipalities have to make a crucial contribution in order to achieve the set targets within the prescribed time frames – since federal and state-wise political competencies, respectively controlling instruments alone are not sufficient.

Development, evaluation and implementation of sustainable concepts in urban planning demands application of integrated concepts and methods based upon early inclusion of all relevant aspects within the complex, dynamic and highly emergent systems „city + energy(flow)“. Due to the complexity involved, it is required taking into consideration prospectively systemic interactions and dependencies. It is also necessary to include all involved planning participants in communal goal definition and planning processes at an early stage. These requirements still pose great difficulties especially for small municipalities. When compared to bigger cities, they have less personnel resources and specialized professional competencies due to less diversification in political and administrative institutions. On the strategic decision-making level a solution-neutral localization of situational proper fields of action often already fails during preliminary planning stages because of poor availability of an up-to-date, transparent and consistent information basis, describing the given local situation.

Frictionless exchange of information along the communication chain is frequently impaired by largely heterogeneous data basis, in form and content, which entails information loss and misinterpretations. This will result in an inadequate efficiency of municipal planning processes, and often also leads to quality deficits in the planning object, or non-archievement of specified targets. A functioning trans-cyclical information management, therefore, necessarily requires an early provision and consistant application of a common, formally standardized and content-related consistent database (Gianella 2005). To define a sustainable urban development concept, it is first necessary to attain an appropriate selection and improved alignement of individual measures.

Essential questions in this regard are a) assesment and selection of the most suitable measures for a specific local problem, b) the long-term utility of these measures as well as c) the contextual coherence of individual measures with each other proportionately in the timeframe of the planning horizon in order to provide one sustainable approach. Creating a sustainable overall concept essentially requires detailed information about the location-specific current situation and strategic objectives. Therefore, the appropriate measures must be identified and evaluated in accordance with their respective capabilities. This requires a holistic situation analysis of, for example, energy consumption situation, supply situation and distribution situation, taking into account all relevant actors and local stakeholders such as residents and users, or respectively, consumers and suppliers (BMBF 2008). The problem context's high complexity and the demand for systematic observations (BMWI 2007) indirectly implicate that developed planning solutions cannot be evaluated directly and with regard to their interaction. As has been shown, both in practice as well as in research, a goal-oriented planning is only possible through consistent integration of optimization processes which support an early validation of solution concepts by means of integrated simulation and analysis tools. An efficient and transdisciplinary application of these information technological tools presupposes the availabilty of an appropriate modelbased information base, the core of which is an integrated semantic information model with a standardized respectively unified type system.

Within the framework of the funding initiative 'Energy Efficient Cities' ('Eneff:Stadt') of the Federal Ministry of Economics and Technology (BMWi) the research project „ISIS – Development of an integrated semantic information model as planning tool", the department Building Lifecycle Management (BLM) at the Karlsruhe Institute of Technology (KIT) has designed concepts and tools for the management and semantical analysis of integrated municipal information models. Based on an integrated multi-scale urban information model, the project focusses on the development of semantic analysis methods and tools.

Before explaining the solution approach and the results of the project, first of all a short overview of the examined fields of research shall be given.

3 REVIEW OF LITERATURE

Ongoing digitilization in economy and society has also reached the building industry and urban development. In terms of the application context of the here presented research project a plurality of different – open and proprietary – models, formates and formal description methods were found. However, most of the solutions depict dedicated domain specific aspects. By examining the technical base respective integration capacity of those most relevant to the projects aim a main focus was set on open and manufactor-independant solutions. Since their application is not bound by licensing and importantly they are more likely to provide a better interoperability and serve more common practical needs especially as regards the public sector.

Furthermore a majority of the standards already share a common base syntax, namely XML. Due to its popularity and application in terms of webservices, especially in recent years, an integrated set of core modeling solution provided by World Wide Web Consortium (W3C) is up to date very well established through-out the domains. Beside the wide-spread use respective support of the XML Schema XSD todays market situation also adopted many of the related W3C specifications as e.g. webservices, eXtensible Style Sheet Languache (XSL) in terms of formating websites and its realization technology XSL Transformation (XSLT).

Note that the following subchapters can only highlight certain aspects of the comprehensive literature review conducted in the framework of the project to ensure a common understanding as needed for this contribution.

3.1 Product data models in building and construction industry

Within the field of building design computer-aided methods and tool were adopted at early stage in terms of digitalization. And thus have interpenetrated today's market situation. At the base of building design processes commonly stands the architectural design. While the first generation of Computer Aided Design (CAD) systems mainly focused on digital development and graphical presentation of 2D, and later on 3D building models the second generation followed a more integrated approach. Thus, the 3D planning matter is described by objects respectively components that besides geometrical and visual representation also faciliate additional explicit semantic information (e.g. object type, quality, function or cost) and allow associative interrelations among them. The object respectively building-component oriented method (socalled Building Information Modeling – BIM) thereby allows the involvement of different professional concerns in a common data model. Importantly, this depiction method continuously carries on through-out the lifecycle of the product (planning – construction – usage – renovation/demolition).

In the mean time many BIM-based applications established in the market superseded classic geometry based drawing tools. Although in pactice some of the proprietary formats are still being used for exchange (e.g.

Autodesks DWG/DFX industry standard) the Industry Foundation Classes (IFC) is more and more recognised as manufactor-independant solution for seamless transfer and integration base regarding collaborative data. The obligatory use of IFC is furthermore established for public building permit process in many countries.

The latest version “IFC 4 Add1” has grown up description possibilities, e.g. sophisticated depiction facility for Heating Ventilation Air Conditioning (HVAC) domain as regards the application context this contribution. Noteworthy on behalf of IFC’s syntax base that – besides the original IFC/STEP schema in EXPRESS language – a XML variant was introduced as ISO 10303-28 (“XML representation of EXPRESS schemas and data“) derivate “ifcXML2x3”. This was technically further optimized by stripping overhead comming from the default XML schema binding and is now applicable as stand alone XSD “ifcXML4ADD1”.

3.2 Data models and formal description method in urban development

Inspite of obligatory use of office applications, early digitilization in spatial planning primarly focussed on representation of spatial-related planning data. Virtual geographic, landscape and urban models were initially used for visualisation purposes – thereby differentiated by their granularity depending on the spatial scale of the focussed depiction matter. However, in recent years the demand has emerged for extended semantic connotation of properties besides the facility to depict geometric respective spatial information only. Thus many different geographic models and description methods were established mainly focusing on requirements of single professional domains or as proprietary data format of commercial software.

In order to streamline the development within this field of standardization in 2002 the ISO 191xxx series was established specifying a common base for geographic information models. Great potentials arise thereby from the Geographic Markup Language (GML) as it provides a common base model for depicting geographic information aimed to harmonize the up-to-date wide spread and heterogeneously implemented use of Geographic Information Systems (GIS). Although promoted in international standardisation initiatives as e.g. INSPIRE for the European countries the support especially on side of commercial GIS is still cumbersome. Besides its harmonizing momentus toward existing GIS solutions, GMLs object-oriented extension facility also builds the base of consequent semantic 3D city modeling approach specified by the Special Interest Group 3D (SIG3D) as the OpenGIS standard CityGML. This open, and to great extend, established standard allows multi-granular depiction of 3D city structures as well as annotation of semantic properties and topological relations. Furthermore, a facility is provided for modular thematic extensions regarding individual domain specific concerns (Application Domain Extension – ADE). Thus it is a predestinated integration basis for energy-related aspects in context of domain-overarching analysis and planning processes on urban scale (see Brüggemann 2015 for a comprehensive overview).

Regarding Germany’s offical data on the one hand, the above mentioned INSPIRE initiative led to the specification of a GML based interface “Normbasierte Austausch Schnittstelle” (NAS) for official land-use and measurment data. On the other hand national regulational code has been formalised e.g. for official urban development planning the “XPlanung” model built on GML provides a digital format to the officially obligatory planning data descriptions. Inspite of these generally harmonized approaches still isolated approaches can be found in official data specification effords e.g. concerning the German Energy Saving Ordinance (ENEV) that in its latest version requires digital input of building energy performance assessment data in form of XML-based “Kontrollsystem” format.

3.3 Model-based information management in collaborative planning processes

A holistic analysis of the processes in spatial planning identified integral parts as a) steering system – operative planning, b) information system – acompanying information management and c) controlled system – spatial planning matter (Laurini 2001). All these parts are tightly interrelated while the binding element and methodically basic structure is provided by the information system (Streich 1998), as it includes the informational basis for steering the processes and thus enables the supervision of the planning effects.

The strongly segregated German urban planning process chains require a better horizontal as well as vertical interlinkage of the involved stakeholder. And this again is not expediently possible without appropiate means in demand-led retrieval, management and provision of information (Lakes 2006). Following the paradigm of Integral Planning to solve complex problem situations requires the application of integral methodologies and tools that are founded upon the early consideration respective weighing of all contextual relevant aspects as well as the inclusion of all involved stakeholder (von Both 2006).

4 UNDERLYING INTEGRATED SEMANTIC URBAN INFORMATION MODEL

ISIS, the „Integrated Semantic Information model for the context of energy-efficient city" can describe and associatively link – in addition to common urban objects and urban aspects, especially regarding the energy-efficient city – all relevant structures, classes, and corresponding ancillary information on different scale. As the following figure shows it therefore faciliates a level over-arching reference system.

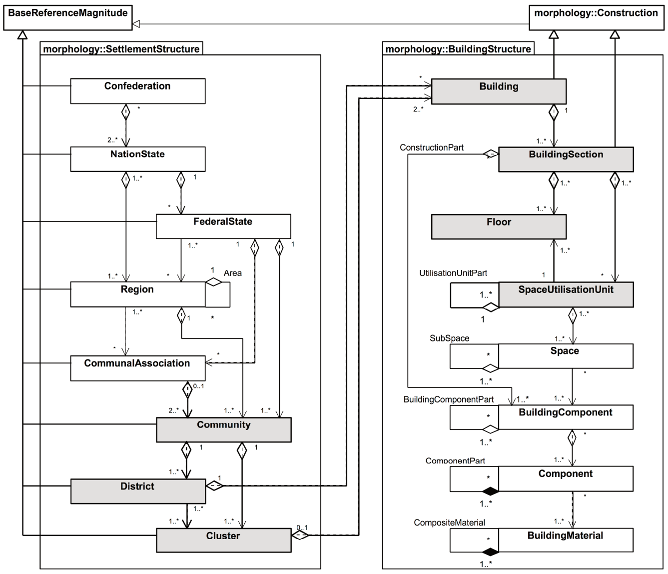

Figure 1: Modeling concept of the base dimensions (partial model 'morphology')

In addition to representing buildings, land uses, territorial or functional boundary lines, and topografical surface structures, within the systemic order of city and energy the model also supports the integral depiction of (topo)logical network infrastructure – supply and mobility – as well as energy-related quality of building structures. The differently modeled dimensions and professional aspects are shown in the following figure 2.

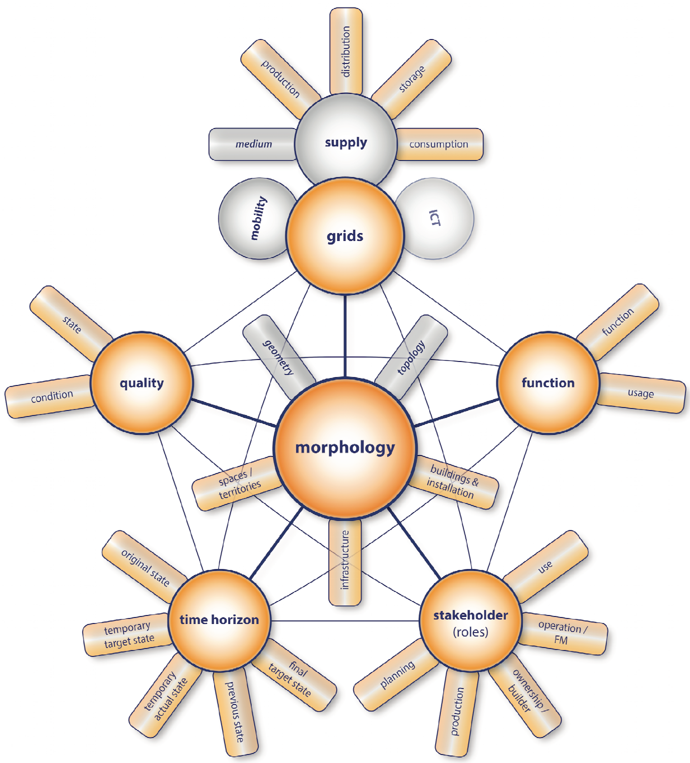

Figure 2: Dimensions and aspects of the urban information model

As a – transparent and convergent – information basis the model can constitute a suitable knowledge base for the strategic level of municipal planning to a) identify local specific deficits more easily, and to b) enable evaluating and prioritizing concerning their effective relevance in the context of energy efficiency. Thus, ISIS also supports political decision-makers in their efforts to define adequate and realistic goals for a sustainable development, context-sensitively. This increases the decision-making reliablity on the strategic level and removes possible constraints towards necessary political initiatives. Regarding a detailed description of the information model, see Brüggemann 2012.

Another objective is the support of the information generation process – that is, the development of a municipal information base building on the developed model. An important approach of the integration effort,, inspite of the technical integration of professional information into the ISIS system model itself on side of modeling, is to prepare the ground on side of the model to enable integrative linking of established professional models and data standards. In order to implement this goal, for the model specially an adequate translation from detailed BIM-based building information – specifically of the established BIM exchange standard Industry Foundation Classes (IFC) – was also projected. In this context an apropiate aggregation and exchange mechanism for the information regarding the individual building – especially concerning energetic aspects – has been concepted and realized as prototype. This involves the development of methods for information compaction as well as mechanism for the technical conversion. Furthermore solution proposals could be worked out as of how such process could be embedded in a supporting way into existing communal planning procedures.

Thus, the here presented system model (ontology model) provides the conceptual and structural base for developing application-oriented planning tools.

5 DEVELOPED MODEL BASED METHODS AND TOOLING CONCEPTS

The evaluation of the system model was based on an application case related translation and prototype implementation of an urban planning tool. In the framework of the project this was accomplished for the use case of a “convoi renovation” urban planning approach. The real-world context out of which this scenario was derived is the beacon project „Effizienz-Konvoi Waldstadt“ sponsored by the state of Baden-Württemberg Ministry for Environment, Climate and Energy Sector. It introduced a new approach to multiply the rate of renovation by harvesting synergetic potentials out of over-arching organisation of multiple renovations of same typed dwellings (KEK 2012). As a research and realisation project it follows the conduction of a scientific feasability study „Klimaneutrales Karlsruhe 2050“ (Vogeley 2011) with the Karlsruher Energie- und Klimaagentur (KEK, local energy agency) and the city of Karlsruhe as official stakeholder.

Following an analysis of existing normative directives and guidelines, a specific process pilot was concepted in close feedback coupling with KEK. Its implemention as a process navigator enables accessing specifically needed information (views) on behalf of the respective processes and working steps (see figure 7).

In order to ensure high flexibility on the data mangement level with regard to the application in existing IT-system environments a link was also projected to well established and practice-oriented data standards. The content management interoperability service (CMIS) is an open and manufactor-independant standard for linking Content Management Systems, e.g. the widespread Microsoft Sharepoint Server. Thus by offering support for CMIS standard with in the framework of practical implementation enables to take into consideration already existing communal system environments.

For further specification of the projected prototype a concrete application case within the above mentioned process navigator was derived. In the course of stocktaking this use case contains the analysis and integration of energetic characteristic value – as required by the German Energy Saving Ordinance (ENEV) – regarding individual buildings into the urban model.

Achieving high practical relevance as well as accessibility to the established object-oriented model formats CityGML on urban level respective IFC on building level was focussed on side of prototype realisation. Thus, the application-relevant partial models of the overall system model were transferred and persisted in XML-based structure. This derived application model was also used by the project partner IAI (KIT Institute of Applied Informatics) as a base of implementation of the convertion tool from IFC to CityGML. Built ontop of this tool then within the project (energetic) building information could be aggregated and integrated

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into the urban model. A model analysis tool also aligned to the above mentioned standards that was implemented within the project enables likewise level (scale) and domain over-arching logical model checking. It furthermore serves as a concrete support tool regarding complex interdisciplinary decision-making processes.

5.1 Further development of preparatory work

In the proposal to the research project it was intended to reuse existing software components from the author's BLM collaboration tool kit (BLM.CTK). This repository is based on mainly self-financed generic software building blocks. It serves in these kinds of application context as a base of implementation. Furthermore as most prototype developments derived in various research projects are uniformly classified within the repository it provides the means for software managment and maintenance.

Thus the main technological base of the projected prototype planning tool was derived from the tool „BBR ModelCheck“ that was also built up on BLM.CTK and developed for the Federal Office for Building and Regional Planning (BBR) in 2011. This model checking software within the framework of the BIM pilot project „Humbold Forum“ in Berlin enables BBR to check incomming IFC model data with regards to the alpha-numeric contents. The software uses seperate rule XML files for depicting the logical checking aspects as derived e.g. from official building code regulations for public buildings. A requirement of BBR to be able to configure respective further develop and administer their rule base stands at core of the rule-based concept. The therefore designed rule XML files and the facility of configuration and administration is described in detail in Ebertshäuser 2013. Further development of the abilities of this stand-alone software was on the one side to extend the application context in order to check different XML-based model types (e.g. CityGML). On the other side, since it was developed on base of generic building blocks developed within BLM.CTK, was refactoring the software to be used as a module rather than a standalone program. Its rule-based facility thereby was used besides checking the contents of the model, to have a uniform way to e.g. manipulate respectivly map certain data, extract partial models.

5.2 Testdata and external expert tool

The associate project partner City of Karlsruhe that had prior to the research project already established a CityGml data basis provided a data set of the concerned district that was used as communal information base of the scenario-project. In addition to that information on city level a IFC building model was chosen as exemplaric information which in terms of the scenario stands for the detailed building information contributed by the participating building owners. With these testdata the last necessary item of the scenario was specified as needed to implement a prototype aggregation mechanism within a framework of a planning tool.

An expert on side of tooling, the project partner IAI with conssesive experience on providing tools for both CityGML and IFC, was involved in the development. As an exemplaric external tool that would be bound in one step of the planning tool's procedure an existing IAI tool the IFCExplorer was further developed to provide the technical mechanism – receiving an IFC building (see fig. 3) model (and needed information of its geo-position) and transforming it into a CityGml representation (see fig. 4). The information flow between the planning tool and this external modeler tool is either possible by having both installed on one system or in case of distributed working spaces by establishing the connection on behalf of the above mentioned CMIS webservice interface.

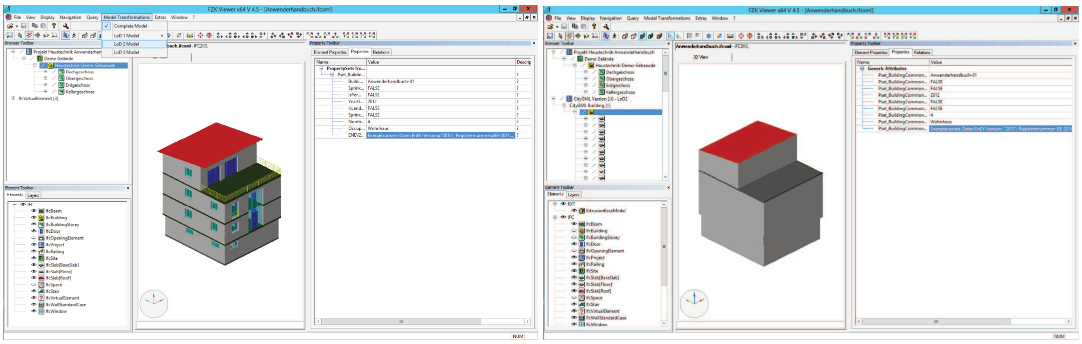

Figure 3 (left): IfcExplorer – loaded IFC model. Figure 4 (right): IfcExplorer – converted CityGML model

5.3 Use Case within process navigator to specify prototype's (functional) ratio

On the basis of the process navigator's overarching workflow – strategic, tactical and operative phase – the thematic basis for a functional implementation of a prototype planning tool was further concentrated to a focus on the operational phase. Here especially the threesome stage of building assement data collected from the participants of the scenario-project – as is, planned respective realised – was found to be a suitable (recursive) task to functionally cover in the prototype software. Furthermore, the hereby also implied aggregation concept to transform the fine granular input information of building-specific information to urban level in order to provide a clearer strategic overview – reflecting the three „building-wise" conducted stages in a combined city wide overview – was seen with potentials for reuse in a more generic manner.

The figure 5 shows the core data exchange workflow as specified for the use case – an organisation team maintaining a central project-model receives a further detailed building model as extended IFC file from a participating building owner and synchronises the CityGML based urban model with this incomming data. In the prototype planning tool this specification is implemented into four different procedure steps. The internally computed steps on the one side trigger a checking respective manipulation rule on a targeted model in respective software modules. And on the other side one step calls the external convertion tool with the corresponding input model as argument, idles while transformation is executed and resumes when the resulting data is returned.

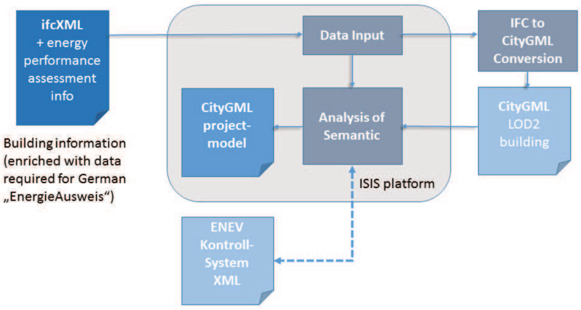

Figure 5: Specification of data flow in implemented use case

6 PROTOTYPE OF A PLANNING TOOL 'ISIS-PLATFORM'

In the following sections the implemented user interface of the prototype planning tool is presented that consists of different modules. First, the generic funcionalty provided by the integrated rule-based model analysis module is described. And then the workflow-based project module with the above mentioned process navigator together with the use case specified in the previous chapter is introduced. Thereby the provided configurable procedures of the implemented use case are explained. On technical side they implement the concept of a unified business logic entity – in each case consisting of separate rule files and a designated software module respective external tool to execute the work task described by the procedure.

Analysis Module – arbitrary model checking facility

While opening the analysis module (see fig. 6) the user decides which model format (e.g. IFC or CityGML) to be checked. This triggers the correct rule repository for the respective format to be loaded while initializing the module.

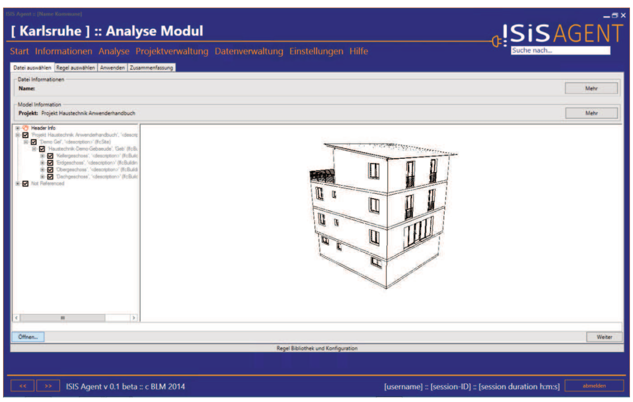

Figure 6: Prototype planning tool – model analysis module

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In order to check model contents this module provides following four straight-forward steps to the user that are implemented in seperate tabs:

(1) open the model file

(2) choose rule(s) for checking the model

(3) execute the model check

(4) summarize the result(s) [and persist report as table file if needed]

Project Modul – demonstration of workflow-based use case orchestration (general platform)

The following sections will describe the planning tool from designated user's view in the municipal level. Firstly if the user as designated member of the organising team opens the convoi renovation project, the current status as overall project-workflow is presented by the process navigator (see fig. 7). Each single step of the workflow by an instance of the underlying application model is connected to information (view) on a) who is involved, b) what is the planning matter and c) what task to be accomplished. Thereby, the previous step's results commonly are the input information to the current step. Furthermore since some steps are obligatory respective flows depict the necessary path of steps to be accomplished.

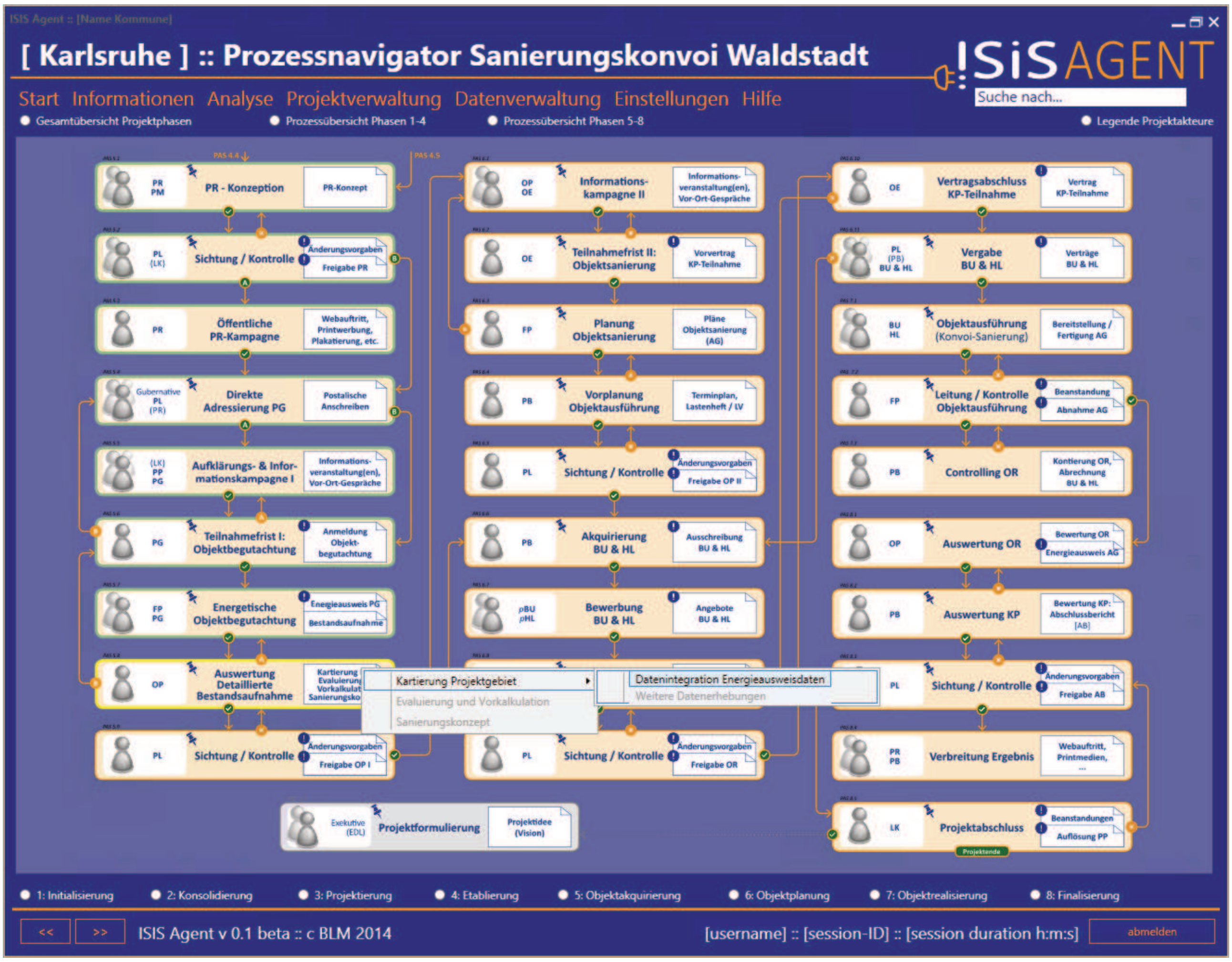

Figure 7: Prototype planning tool – process navigator of project module

The purpose of the process navigator is to enable – besides an above mentioned current status overview on the project – choosing a specific task from one of the depicted workflow steps. This is implemented as a context menu underlying the representation of the planning matter within the workflow step depiction. Thus, the user can load an associated task into the project module in order to accomplish the required work. In the prototye – as the introduced use case specifies a collection of IFC building models that have been uploaded in a previous step by participating building owners to be synchronised with the central urban project-model – this has been implemented as a tasklist for each building model. Each task thereby consists of four subprocedure step, where the accomplishment of the previous step enables the button to trigger the next step (see fig. 8).

Preliminary while opening the project, the concerned city quarter is loaded with a rule that filters all buildings of the owners participating in the Renovation Convoi scenario-project from the communal CityGml data base. This cached partial CityGML model is now updated building-wise with the received information. Extracting this partial project-model dynamically also builds the base for continiously versioning the information compaction taking place in context of the project with regard to the state of the central urban data basis.

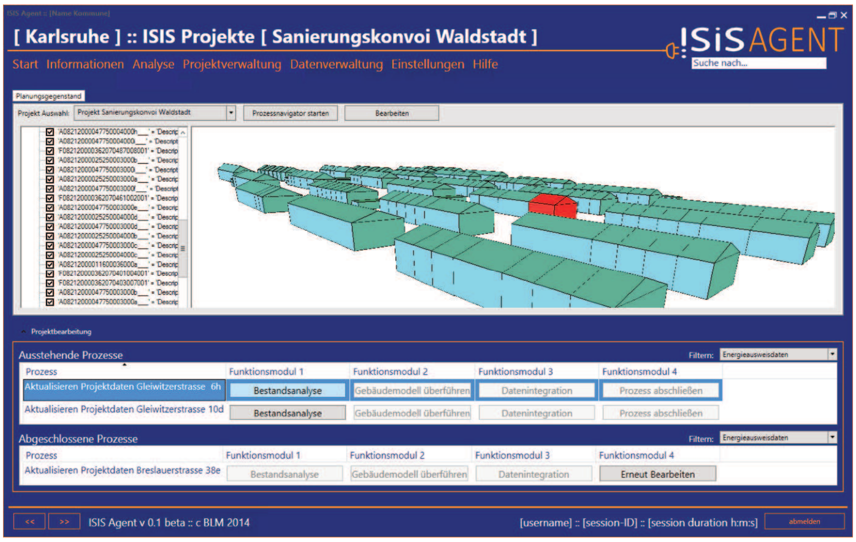

Figure 8: Prototype planning tool – project module with loaded project

The highlighted first task below the depiction of the project-quarter in figure 8 shows the four steps to synchronize the project's citymodel with new information comming from one of the IFC files with energetic assessment information on the respective building.

- Step 1 (filter the to be updated building from project-model): In order to have the current state of a buildings' information in the project-model (e.g. geographic location).
- Step 2 (employ external tool for transformation): Together with the location information the IFC file carrying the to be updated energetic assessment information are opened in the external modeler IFCExplorer where the transformation from a IFC building to a CityGML building is executed (see fig. 3 and 4). Finally after the resulting transformed CityGML building is returned this step is accomplished.
- Step 3 (integration of new data into project-model): Having all necessary data at hand – results of previously processed steps are intermediatly persisted and thus can be accessed by following steps – the project-model can be synchronized. Therefore a manipulation rule containing the exchange-procedure replaces the current building in the project-model with the transformed building (Fig. 9)

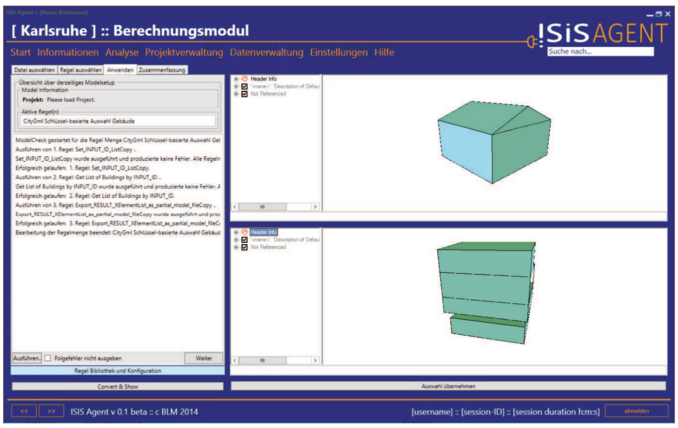

Figure 9: Prototype planning tool – rule-based configurable step

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- Step 4 (completion of the procedure of the currently worked on building): In this step the synchronization procedure is finalized and the completed task is moved to the list of resolved tasks.

By applying the presented procedure repetitivly – update a CityGML building with information received as IFC building – the central CityGML-based project-model is gradually enriched with more accurate information regarding energetic performance of the contained buildings. Thus on this base integrated analysis with the developed ISIS analysis module on city scale can be accomplished, in terms of the defined scenario this e.g. can be an (strategic) overview on the energy consumption of the projected quarter before, during and after the implementation of the scenario-project.

7 SUMMARY

The presented research project examined a designed urban system model in the context of an urban development planning scenario. Thereby, throughout modeling and specification effort putting a major emphasis on the integration respective linkage of established standards. Thus the model-based methods and according tooling concepts derived from the specific development bear great potential of reusability. The method of deriving an application-oriented model from a holistically designed system model furthermore provides a base from where of further application contexts can be approached. As the presented thematic was concerned with energy-efficient urban structures a projected further application context is the super-ordinated lifecycle assement on urban scale.

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