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IMPROVING ENERGY EFFICIENT OPERATION OF BUILDINGS WITH WIRELESS IT SYSTEMS

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Abstract. *Reducing energy consumption is one of the major challenges for present day and will continue for future generations. The emerging EU directives relating to energy (EU EPBD and the EU Directive on Emissions Trading) now place demands on building owners to rate the energy performance of their buildings for efficient energy management. Moreover European Legislation (Directive 2006/32/EC) requires Facility Managers to reduce building energy consumption and operational costs. Currently sophisticated building services systems are available integrating off-the-shelf building management components. However this ad-hoc combination presents many difficulties to building owners in the management and upgrade of these systems. This paper addresses the need for integration concepts, holistic monitoring and analysis methodologies, life-cycle oriented decision support and sophisticated control strategies through the seamless integration of people, ICT-devices and computational resources via introducing the newly developed integrated system architecture. The first concept was applied to a residential building and the results were elaborated to improve current building conditions.*

1 INTRODUCTION

Due to emerging demands for the provision of an energy performance rating of buildings in EU Member States and for the reduction of energy consumption by 20 % before 2020, much effort is currently invested in energy-efficient building design. Also at the moment sophisticated building services systems are available for facilities management. However, their focus on energy performance rating of buildings is at best sporadic often consisting of an ad-hoc combination of off-the-shelf building management systems (BMS). This ad-hoc combination presents many difficulties for building owners in relation to the management and upgrade of these systems, as the BMS can consist of a number of components utilising various information exchange protocols that have to be integrated within the M&T software packages [1]. Moreover the prospective consequence of the building behaviour and the needs of the building occupant/operator which would manage energy consumption efficiently would not be predictable with a single combined information and communication platform. A promising approach, to overcome these shortcomings, is the implementation of a holistic, modular infrastructure [2].

This paper describes improving energy efficient operation of buildings with wireless IT systems through the intensive analysis of building performance data. The paper is based on early research results of the strategic research cluster “ITOBO” (Information Technology for Optimised Building Operation) a joint research project of 7 research groups and 5 industry partners from Civil Engineering, Computer Science and Electronic Engineering funded by Science Foundation Ireland.

The aim of ITOBO is to enhance the management of large-scale, complex networks, services, and mobile users through introducing new network and management protocols, to develop frameworks and algorithms to support mixed-initiative configurations for energy efficient buildings, to support seamless end-to-end network composition and service operation through sensor and RFID hardware with dynamic features [3].

In this context four scenarios were developed: (1) Data Representation and Aggregation, (2) Building Performance Analysis and Diagnostics, (3) Scheduling and Management of Maintenance Activities and (4) Intelligent Building Control.

The first scenario addresses the need for easily understandable representation of different data streams to various stakeholders (e.g. owner, operator, user/tenant) via wireless embedded monitoring and control systems. This scenario provides the information basis for smart building operation and leads to intelligent control. The second scenario presents the need to carry-out automated building performance analysis and diagnostics based on systematically-developed building performance framework. Moreover, it addresses the need to optimally design and layout a wireless sensor and actuator network. The third scenario focuses on the maintenance actions derived from regular (a) maintenance requirements and processes, (b) user reports and (c) building performance data and diagnosis. The actions will be scheduled to optimise energy efficiency, cost effect and user satisfaction, while respecting constraints and preferences over resources, engineer availability and building use. The fourth scenario addresses the intelligent control of buildings based on the preferences of building occupants and building operators via the user preference interfaces. The information is processed to enable predictive maintenance and optimise building operations. In this paper the first scenario *Data Representation and Aggregation* will be presented in detail.

2 SYSTEM ARCHITECTURE

This architecture represents a new and affordable ICT for energy-intensive systems for: (1) design and simulation of energy use profiles covering the entire life-cycle of energy-intensive products (manufacturing, use and disposal), services and processes; (2) intelligent and interactive monitoring of energy production, distribution, trading and use, e.g. intelligent metering, network management, in-house consumption management; and (3) innovative tools, business models and platforms for energy efficiency service provision providing continuous and accurate information to decision makers, in industry and policy making [5].

A promising approach to achieve a consistent structure should consider the implementation of a modular platform that integrates multiple dimensions of building information such as performance data (e.g. energy consumption, temperature, light), system data (e.g, status, switch settings) and process data (e.g. inspection, maintenance, repair) and should support integration concepts, holistic monitoring and analysis methodologies, life cycle oriented decision support and information and communication technologies.

In order to comprise all these issues the consortium provided the ITOBO system architecture as depicted in Figure 1. The result of the decomposition is specified in the form of UML-package diagrams. The architecture is implemented as an extension to international standards (e.g. IFC 2x2 ISO/PAS 16730, ISO-STEP 10303).

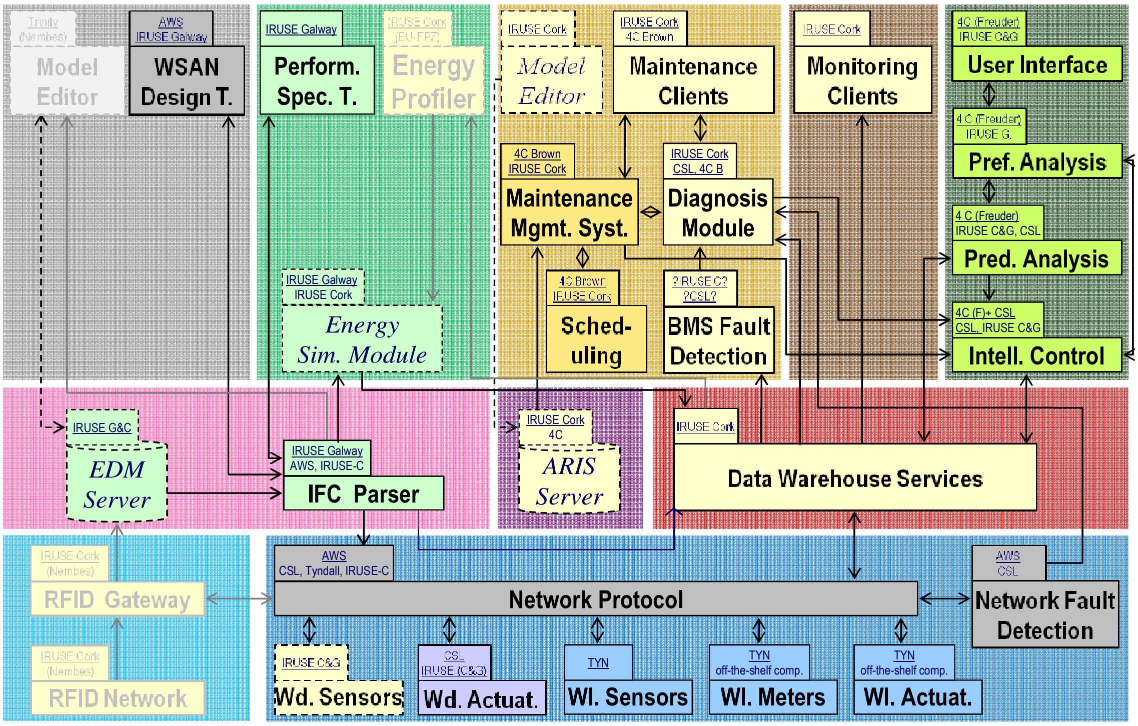


Figure 1 Proposed ITOBO Architecture

2.1 Data representation and aggregation

This scenario as depicted in Figure 2 addresses the presentation of different data streams to various stakeholders to obtain useful information relating to the energy performance of their buildings. This supports improved alterations of the current conditions and leads to an intelligent control of the buildings, which addresses our fourth scenario; Intelligent Building Control. Data acquisition is based on the wireless and wired sensor / meter network. The performance data includes (1) Energy Consumption Data (conventional and renewable sources) (2) User Comfort Data (Temperature, CO2-level, Humidity, Lux-Level), (3) Environmental Impact Data (CO_2 - Footprint).

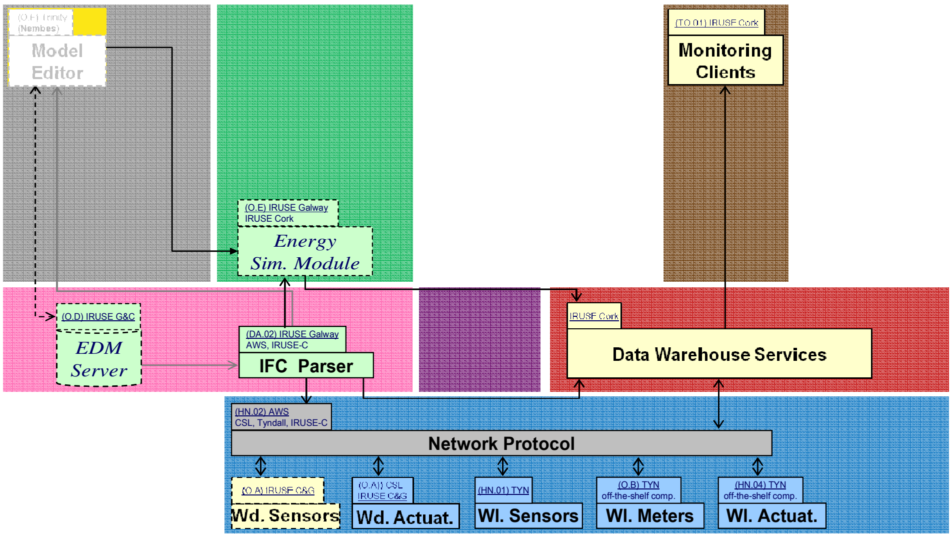


Figure 2. UML Package Diagram for Data Representation and Aggregation

On this basis, three processes that involve collection and interpretation of building performance data will be described. Figure 3 depicts, a UML sequence diagram the extraction of raw data from the wireless network as.

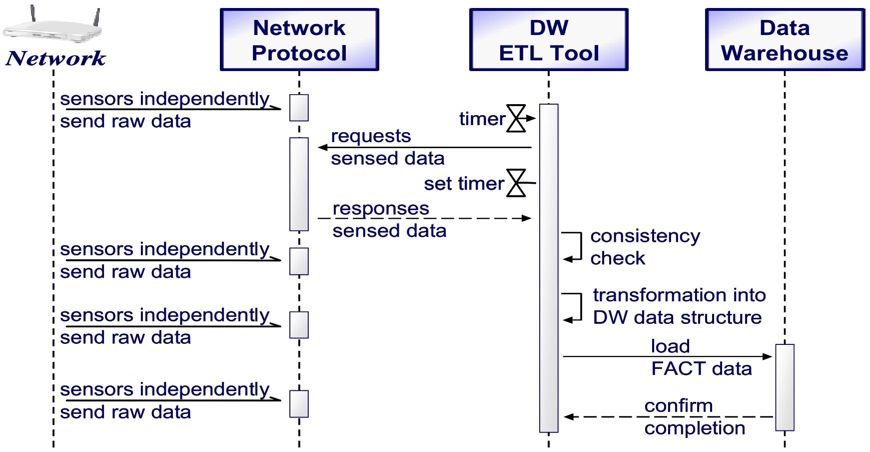


Figure 3. UML Sequence Diagram for Scenario 1: Data Extraction and Loading from WSN

The data warehouse dimensional data (e.g. room in a building and its usage) needs to be updated over a building lifecycle from the information in the BIM as given in Figure 4.

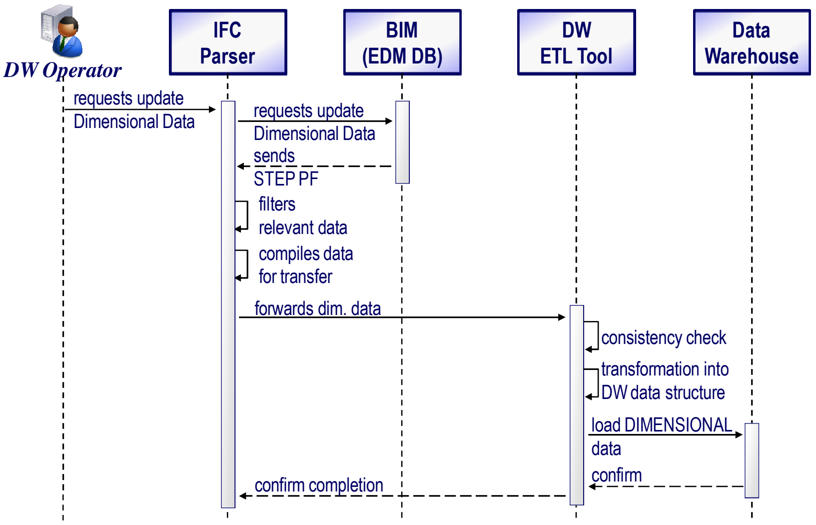


Figure 4. UML Sequence Diagram for Scenario 1: Collection of building information to form data warehouse dimensions.

The sequence diagram depicted in figure 5 addresses the owner requests for energy consumption and information representation. The interest of the building owner is to oversee the energy consumption of the overall building, as well as of individual tenants to specifically control costs and create bills. On the other hand, the tenant and occupants are primarily interested in their own user comfort at their location (room/zone) and less in the energy consumption. Building operator compares energy consumption and user comfort, as his interest is to provide a steady high level user comfort at a minimal energy consumption to increase efficiency. Thus, operator is interested in the energy consumption as well as the user comfort of the tenants.

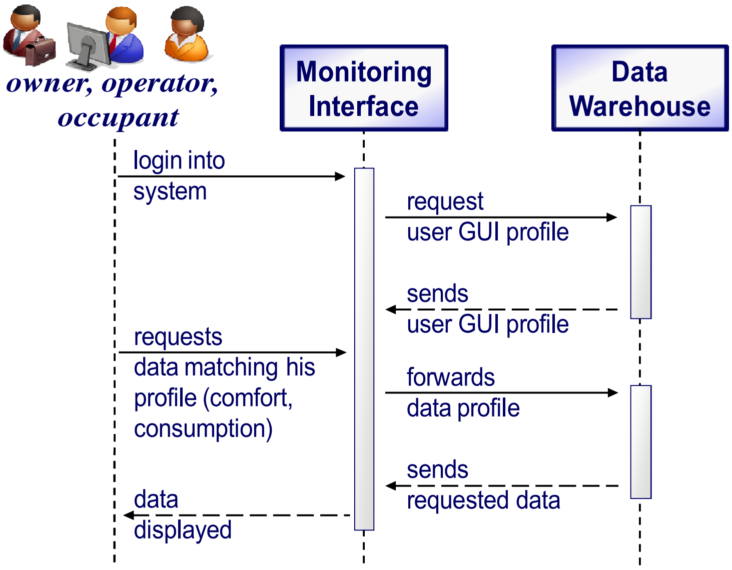


Figure 5. UML Sequence Diagram for Scenario 1: Information representation.

3 FUNDAMENTAL CONCEPTS

This section gives an overview of the fundamental concepts involved in order to create an energy efficient building operation platform. As building operation is an important part of FM the proposed solution needs to incorporated to the existing models. Also, Building Performance Models (BPM) should be considered as an extra feature to the current FM scenarios. Furthermore, Building Information Models should provide the required building information specific to energy efficiency. Moreover, wireless sensors, wireless network and data communication protocols should be tailored towards energy efficient building operation. Finally, current data warehouse practices for information management is reviewed.

3.1 Building Operation and Facility Management

Building operation is a critical aspect of FM. German Facilities Management Association (GEFMA) gives the following definition; FM is a discipline which fulfils people's basic requirements at work, supports core company processes and increases return on investment by result oriented use of facilities and services within the framework of planned, managed and controlled facility processes[1]. In "Facility Management Towards Best Practice" five widely used models in Anglo-American society are described as follows [6]:

- Office Manager Model is an approach where FM is a role under taken by an office manager. The office manager is responsible for decision making, budgeting and expenditure. FM tasks are usually carried out by consultants or contractors where necessary.

- Single Site Model constitutes an organisation which has a FM department but operate only on a single site. FM activities can be assigned in-house and/or contracted services. The FM group decides how to distribute the allotted budget.

- Localised Sites Model consists of organisations that have buildings in multiple sites. FM jobs are assigned in-house and/or contractors. The headquarters (HQ) control expenditure, policy and technical assistance while operational decisions can be made locally, on site.

- Multiple Sites Model applies to large organisations that operate over a large geographical area. Operational tasks are under taken at regional level. The HQ role is to ensure resource allocation, standard setting, policy, planning and project management.

- International Model externs the Multiple Sites model for organizations that operate across international boundaries. The FM team at HQ provides policy, standards and resource allocation. Regional offices are responsible for operational tasks and allocation of budget.

Based on these location based models, proposed system must be capable of operate multiple buildings distributed over a large geographical area.

3.2 Building Performance Models

Numerous building performance assessment frameworks are being developed in the US and Europe in order to monitor Building Lifecycle (BLC) stages; design, construction, commissioning, and operation & maintenance.

Building performance assessment framework examples such as the International Council for Building (CIB) Performance Based Building Program [7], US Green Building Council's LEED Green Building Rating System [8], the International Code Council (ICC) Performance Code for Buildings and Facilities [9], and the US Department of Energy (DOE) High Performance Metrics Project [10] provide platforms to describe facilities. Initial building performance assessment is carried out at the design stage utilising various simulation tools. Further assessments are carried out in the form of commissioning tests, but there is little or no monitoring or feedback once the building is occupied [11]. As a result, Directive 2002/91/EC by the European Parliament for energy performance of buildings was accepted in 2003. The directive requires owners to quantify the energy usage of their buildings against benchmarks set by government agencies throughout the building life cycle.

Another approach to building performance assessment is the use of energy-related performance metrics [12].The scenario modelling technique for holistic environmental and energy management provides a flexible framework to incorporate overall building operation in the context of the building energy manager [13]. This performance framework provides a suitable platform to translate building performance data in respect to operation levels through the application of standard engineering formulae. Examples include the US DOE High Performance Metrics Project [10], the ANSI/ASHRAE Standard 105-1984 [14]. Entitled "Standard Methods of Measuring and Expressing Building Energy Performance" and CIBSE Guide F [15] which highlights Energy Use Intensity (EUI) values, measured in kWh/m2/per year, for different building types.

3.3 Building Information Models

The concept of a Building Information Model (BIM) describes an integrated data model that stores all of the information relevant to a building throughout the building life cycle. The BIM is a central data model where all information can be accessed by a variety of tools dealing with the entire building definition [16].

3.3.1 Model Editors

The capabilities of four different CAD systems were investigated. These systems were Autodesk Revit, Microstation, ArchiCAD and DDS-CAD. Not only the modelling capabilities of the software were investigated but also the interoperability of these systems was investigated with regard to the IFC compatibility. Additionally, we explored the Express Data Manager (EDM) server and its uses from a BIM perspective. In terms of IFC, all CAD systems are compatible with the latest version of IFC 2x3, but DDS-CAD is actively involved in the development of the latest version IFC 2x4. From interoperability perspective, all CAD systems claim to offer some form of import/ export between systems.

Based on available resources and previous user experience Autodesk Revit (Autodesk Architecture and MEP (Mechanical Electrical and Plumbing) which is specifically for design and documentation of building services [17], was chosen to carry out the BIM creation and editing. A factor in this decision was the inbuilt MEP systems design and IES energy simulation plug-in.

3.3.2 Energy Simulation Models

Energy simulation for this particular study was performed on the Revit MEP model using the provided Integrated Environmental Solutions (IES) plug-in. IES is an energy simulation software package [18]. It is broken into a number of separate tools which are purchased and licensed separately. Some of the most relevant tools are detailed below.

Model IT is the IES tool used to create the geometry for a building model (AutoCAD *.dfx drawings can be used as a template or models can be constructed from scratch using known dimensions). Building orientation, location and weather files are also specified with the Model IT tool.

Suncast simulation performs solar geometry studies both for thermal heat gains analysis and daylight analysis which is used for site orientation and solar thermal heat gains which provides useful information for glazing/ shading specification.

MacroFlo is a tool used where natural ventilation or mixed mode ventilation is a strategy employed in a building. It is a bulk air flow analysis tool which considers building geometry, wind patterns and internal conditions.

ApacheSim is the central thermal analysis tool which brings together data from other tools to compute the energy consumption of a building and a wide variety of other energy related loads. *Vista* is used for analysis of the detailed results are produced which can shape the design of a building and the MEP services.

IES's Revit plug-in Toolbar allows Revit Architecture and MEP to import a 3D BIM model into IES's software and undertake energy and thermal analysis [18]. No model rebuild is required within IES, an interface 'Setting Model Properties' guides the user. Information is required regarding building type, construction materials, and heating and cooling system types. This information can be entered for the whole building as one set of data or at room (space) level depending on stage of design or results required. Once the model is established, all IES performance analysis products are accessible for the model.

Therefore Revit MEP when combined with IES provides a useful integrated building information modelling and energy simulation package.

3.4 Data Warehouse Solutions

A data warehouse is a subject oriented, integrated, time varying, non-volatile collection of data that is used primarily in organisational decision making [19]. According to Widom "The topic of data warehousing encompasses architectures, algorithms, and tools for bringing together selected data from multiple databases or other information sources into a single repository called a data warehouse, suitable for direct querying and analysis" [20].

The objective of the project specific data warehouse core development is to provide a holistic information management system to store integrate and analyse complex data sets from multiple information sources such as model editors, energy simulation tools and data streams collected from wired and wireless sensors and meters in order to analyse building performance data and to support decision making process of the stakeholders

Figure 6 shows holistic N-dimensional information management architecture which is structured under Data Warehouse Services.

The system consists of three integrated main components

- Data warehouse core
- Extraction, Transformation, Loading (ETL) Tool
- Information representation tools

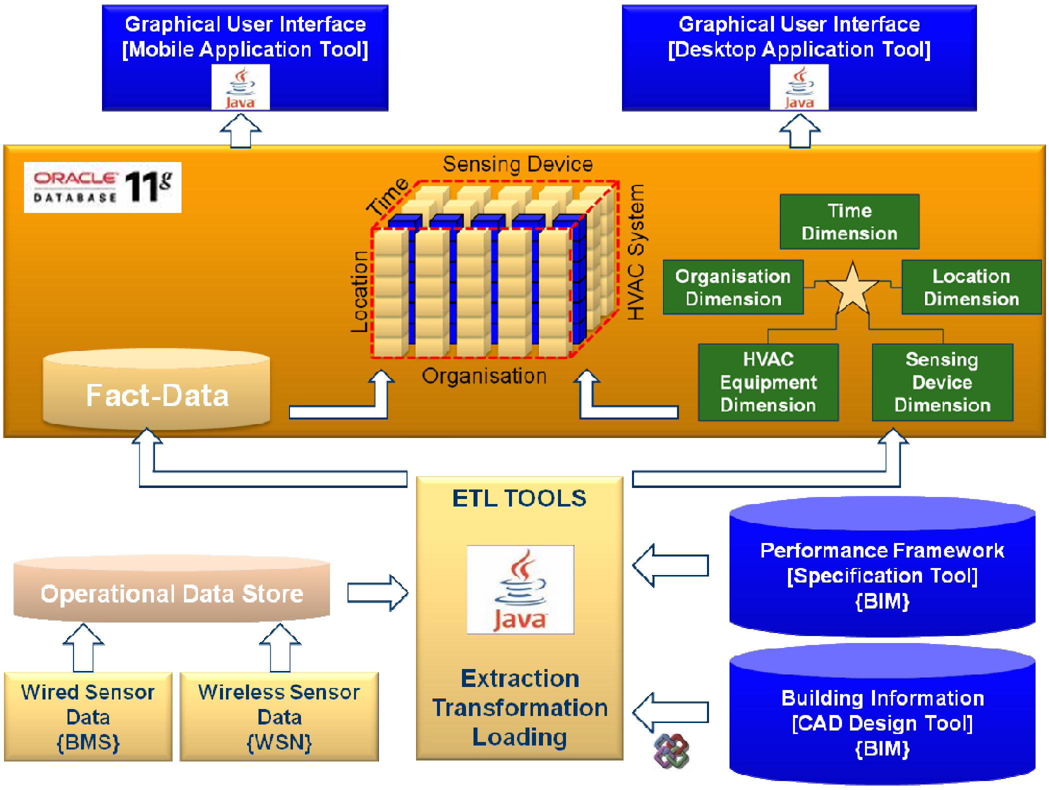


Figure 6. Holistic N-Dimensional Information Management System Architecture

Data warehouse core consist of three subcomponents. These are:

Operational Data Store: ODS is a database designed to integrate current valued subject oriented, volatile and real time data from multiple sources such as building management system, wireless sensor network and energy unit prices.

Fact Data and Dimensional Data: This is the main repository for long term storage of dynamic data. Data is collected and temporally stored in the ODS populates the fact data table.

Aggregated Data: This is the decision support level of the multi-dimensional data warehouse. Fact data becomes meaningful when it is associated with the dimensional data and provides the end user the means to "slice and dice" data.

Proposed system extracts wired sensor data from building management system and wireless sensor network. Collected sensor data is stored in the operational data store for data cleansing and redundancy check processes.

These pre-processed data are loaded to the fact data section of the data warehouse system via ETL tool. Simultaneously, data gathered from BIM (from model editors and building simulation models) is loaded to the dimensional data section of the data warehouse. Populated fact data and dimensional data is aggregated with regards to different stakeholder requirements in the data warehouse core and presented through specific Graphical User Interfaces (GUI).

3.5 Wireless Sensors

Wireless sensors can be developed to detect and measure various parameters such as temperature, humidity and water/gas/electricity meter readings. A sensor node in a network, called a mote, mainly consists of 3 components; the sensor interface which actually measures the physical attributes like humidity level, the radio interface which communicates with other motes and the CPU which performs computations and transfers information between the two components [21]. Figure 7 depicts Tyndall 25mm wireless sensor module with components.

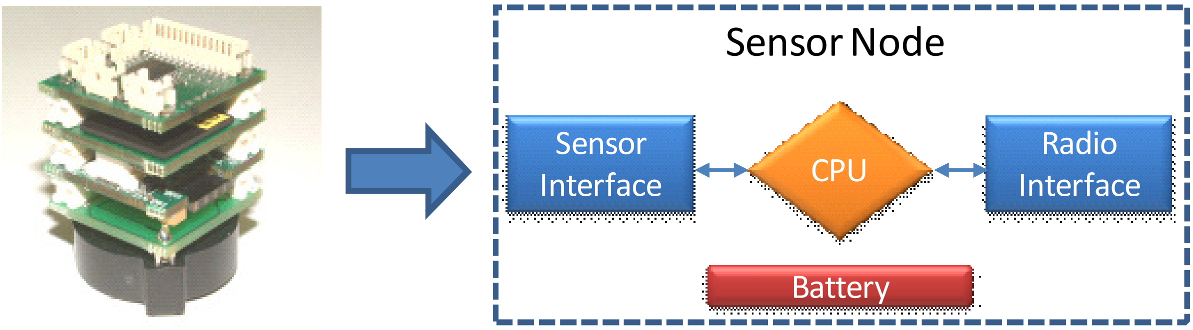


Figure 7: Tyndall 25mm wireless sensor module with sensor node components

The Tyndall 25mm wireless node is the product for platforms of low volume prototyping and for research in the Wireless Sensor Network (WSN) domain specifically for BuildWise [22] and ITOBO projects. It has been developed for use as a platform for sensing and actuating, for use in scalable, reconfigurable distributed autonomous sensing networks. The system has the capability to implement a variety of Industrial, Scientific, Medical (ISM) band transceiver protocols including the 2.4GHz ZigBee (IEEE 802.15.4) standard transceiver, which provides a very powerful customisable wireless sensing system and can be easily deployed and tested in a particular application.

3.6 Wireless Sensor Network

Wireless Sensor Network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors that allow the physical environment to be monitored at high resolution. These sensors also called motes, are installed in particular locations or can be sprayed in a particular zone to gather information such as temperature, humidity, CO_2 , lux level, etc. Sensors are not powerful. The real functionality of sensors comes with wireless sensor networks when these tiny sensors start communicating with each other through wireless protocols. WSN can shuffle the information collected through thousand of sensors and transfer it to the public internet and or a local area network. Finally, the information is collected in the data warehouse where it is analysed. Figure 8 depicts a sample WSN.

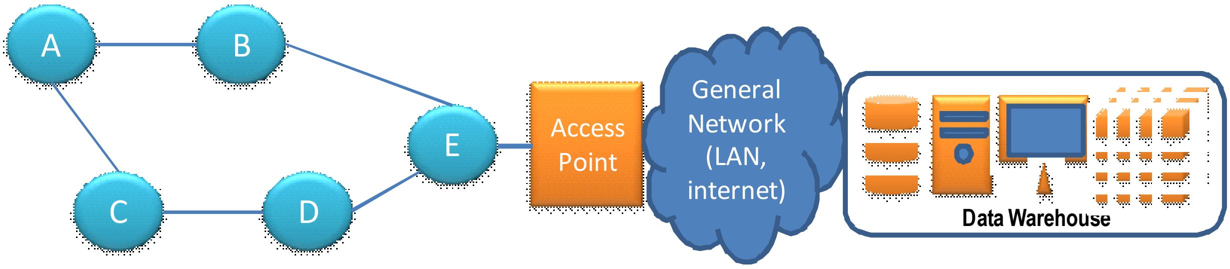


Figure 8: A Sample Wireless Sensor Network

Various network topologies exist but in our case, mesh network is the preferred topology as it provides multiple routes between peer nodes via multi-hop communication rather than simple one-hop star or single route tree topologies.

3.7 Network Communication Protocols

A standardized network data communication protocol is essential for building performance monitoring. The following paragraph gives an overview about selected relevant standards.

ZigBee is a wireless communication technology that provides a suite of high level communication protocols using small, low-power digital radios. ZigBee uses the IEEE 802.15.4 standard for wireless personal area networks (WPANs). The technology is intended to be simpler and cheaper than other WPAN protocols (e.g. Bluetooth). ZigBee is targeted at Radio Frequency (RF) applications that require a low data rate, long battery life, and secure networking.

BACnet is a Data Communication Protocol for Building Automation and Control Networks. It supports six different underlying network technologies. BACnet has been under development under the auspices of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) since June 1987. BACnet is an American national standard (ANSI / ASHRAE Standard 135-2004), an established European standard, a world standard and a national standard in more than 30 countries.

Modbus is a serial communications protocol published by Modicon in 1979. It has become a de facto standard communications protocol in automation and control. Modbus allows for communication between many devices connected to the same network.

4 CASE STUDY: TOKI BUILDING

Data representation and aggregation scenario is implemented with a building information model and energy simulation of a residential building located in Istanbul, Turkey. The building modelled is a social housing tower block. The same building design is to be repeated on different construction sites of Kiptas [4]. The building has 14 storeys including a double basement. In order to implement the scenario following steps were undertaken; (1) Building was modelled using building information modelling editor. (2) Building systems were modelled. (3) Building energy performance was simulated using the energy simulation tool. (4) Wireless system design was deployed. (5) Data warehouse services were implemented.

4.1 Modelling the Building

The BIM for this project was created using Autodesk Revit Architecture. The information that was taken from the Kiptaş drawings was used to create a BIM (see Figure 9) that can be easily used and information can easily be obtained from.

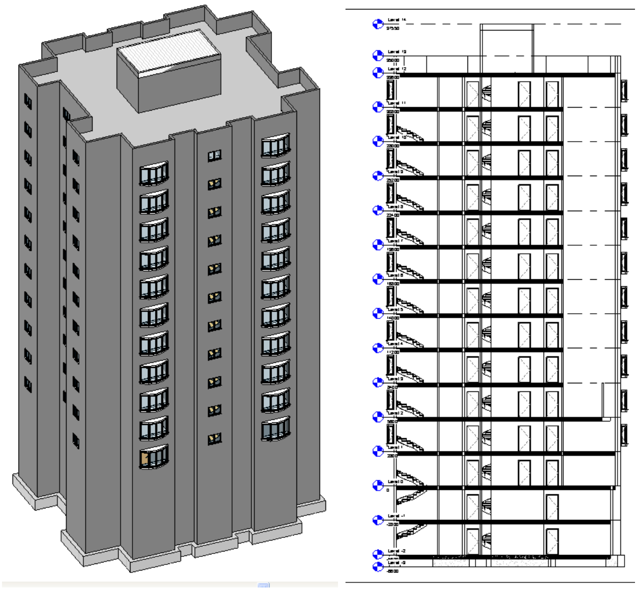


Figure 9 Revit Architecture Model and section created from Kiptaş drawings

The Building Information Model developed with Revit Architecture is saved during design as the native *.RVT file format. The building model can be exported using the IFC format to an IFC-certified application that does not use the RVT file format. The model can be opened and worked on in the non-native application. Similarly, in Revit Architecture one can import an IFC file, create a RVT file, and work on the building model in Revit Architecture.

4.1.1 Modelling the Building Systems

A completed 3D BIM model which was created using Autodesk Revit was the starting point for addition of MEP systems. The mechanical and electrical systems produced for the Revit MEP model included combination boiler radiator heating system, extract fan ventilation system, domestic water supply, hot water supply from combination boiler, soils and waste removal and gas supply for the aforementioned combination boiler.

Revit produces excellent 3D and 2D drafting drawings and intelligent 3D object based building models, however it does not perform energy simulation on the model. The Revit model was combined with IES for a dynamic thermal simulation to analyse variables such as location, orientation, constriuction, plant/equipment, use etc.

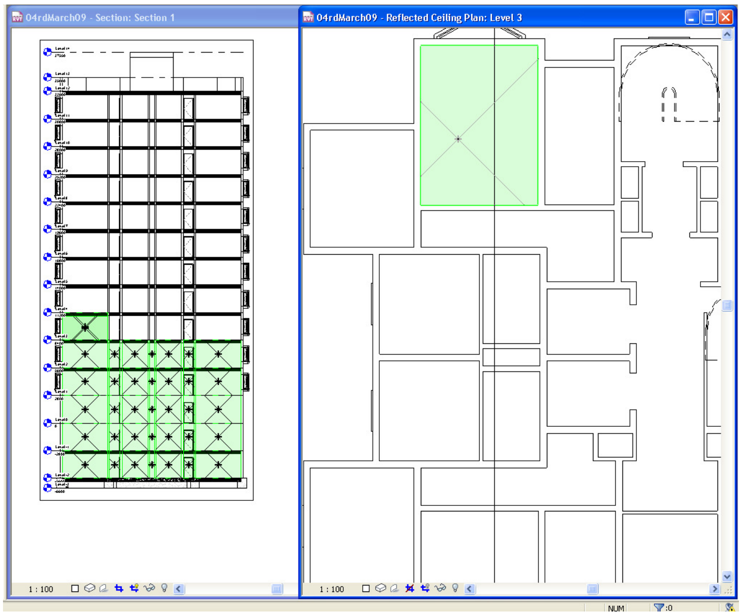


Figure 10 Separation of Spaces

Separate room spaces/volumes need to be identified on the model for IES to recognize them (see figure 10). This procedure is done graphically using side by side views of plan and section. Once created, each individual volume can be renamed for location and type of use.

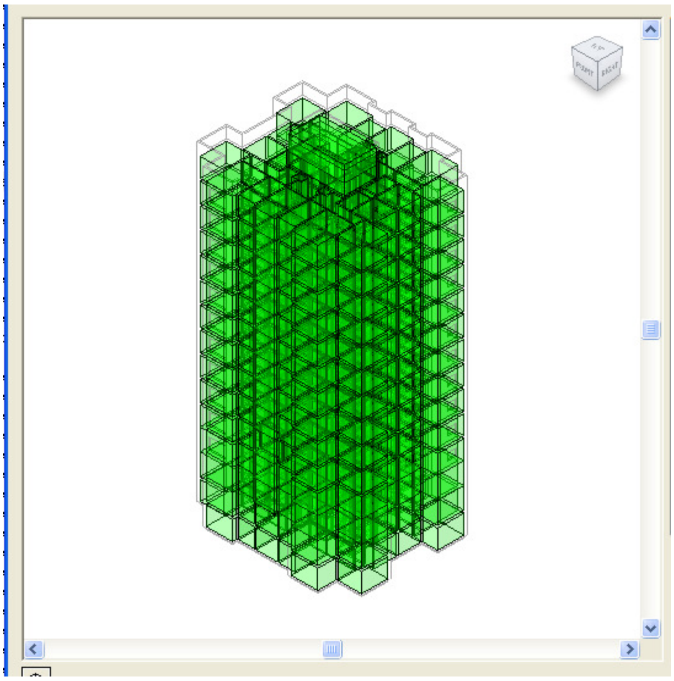
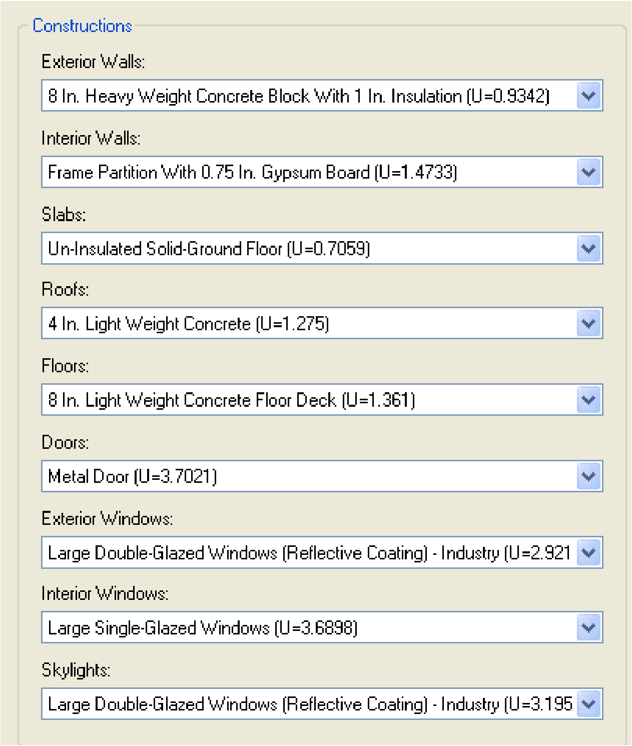


Figure 11 Setting Heating and Cooling Loads

Heating and Cooling Loads (see figure 11) allows variables relating to Building Type, Construction, Services and location to be altered. For example type was set as Multi Family for separate families homes within a single building structure and Services were set as “Central

Heating Radiators”. Options for Construction and Place and Location opens separate windows as shown below.



Exterior Walls:
8 In. Heavy Weight Concrete Block With 1 In. Insulation (U=0.9342)

Interior Walls:
Frame Partition With 0.75 In. Gypsum Board (U=1.4733)

Slabs:
Un-Insulated Solid-Ground Floor (U=0.7059)

Roofs:
4 In. Light Weight Concrete (U=1.275)

Floors:
8 In. Light Weight Concrete Floor Deck (U=1.361)

Doors:
Metal Door (U=3.7021)

Exterior Windows:
Large Double-Glazed Windows (Reflective Coating) - Industry (U=2.921

Interior Windows:
Large Single-Glazed Windows (U=3.6898)

Skylights:
Large Double-Glazed Windows (Reflective Coating) - Industry (U=3.195

Figure 12: Setting Building Element Construction

The IES plug-in allows nine construction variables to be specified. These were chosen for the Kiptas building as follows:

- Exterior walls were set as Heavy Weight Concrete,
- Interior Walls set as Frame Partition with Gypsum Board,
- Slabs set as Concrete,
- Roofs as Light Weight Concrete,
- Floors as Light Weight Concrete Deck,
- Doors as Metal Doors,
- Exterior Windows varied for different simulations see Section 4.1.2,
- Interior windows left as default as they are not contained in this building,
- Skylights left as default as they are not contained in this building.

The simulation and calculations for the building took approximately 4 to 5minutes.

4.1.2 Simulation Results

A number of simulations were performed altering different building façade properties for comparisons.

For example; a simulation was performed with poor quality single glazed windows with a u-value of 5.5475w/m^2°C. This resulted in a total heating load of 134kW for the building or 72 w/m^2 which is a reasonable result. The second simulation performed replaced the poor quality single glazed windows with Double Glazed Reflective windows having a u-value of 2.921 w/m^2°C. This resulted in an improved total heating load of 116kW for the building or 63 w/m^2. For the building type and climate this can be considered to be a reasonable result. This also proves that the Revit/IES programme responded correctly to the improved construction.

All results provided can be considered to be reasonable and accurate. When the entire design process is taken into account, the benefits of Revit Architecture and Revit MEP are clear to see. BIM properties have huge potential to save design and construction time and the software has the potential to become the central hub of any future complex design. Moreover this integration supports a holistic framework for information management and decision support.

4.2 Wireless System Deployment

Wireless sensors are not currently widely utilised because of their supply cost, for example in Ireland a traditional wired sensor can be supplied and programmed for approximately €70 per point whereas a similar wireless sensor may cost approximately €100 per point. However as the technology improves and scale of manufacture increases their use will become more economical, furthermore wireless sensors reduce labour costs with less on site wiring which will add to their value. The two primary advantages of wireless sensors is ease of installation, commissioning and their easy mobility. Moreover *Wireless Embedded Monitoring and Control Systems* may easily be added to old and new buildings and enable the reduction of the energy-consumption by 5 to 30 percent [23, 24, 25].

The likely installation costs for a single apartment were determined using a number of assumptions as given in Table 1.

Assumptions	Wireless System
Controls Supply and Commissioning	€ 4,200.00
Electrician Wiring and Installation	€ 60.00
Main Contractor Builders Works	€ 100.00
Total Cost	€ 4,360.00

Table 1. Wireless System Cost Allocation

This rough estimation has been made using the following assumptions;

- Irish supply of controls equipment
- Typical EU electrician labour cost of €60 for electrician & apprentice
- Builders works assuming minimal concrete disturbance

This estimation gives very general cost estimation for a single independent apartment.

Costs would be further reduced if the building was taken as a whole and controlled centrally. This would be achieved for both systems by requiring less controllers and wireless receivers.

4.2.1 Wireless System Deployment Summary

The wireless scheme design above provides a self contained and practical wireless control system for heating, ventilation and lighting within a residential unit.

For efficient energy management, the monitoring of buildings current energy consumption is of central importance, to identify and eliminate energy wasting processes. In extension, the implementation of an appropriate Building Control Systems permits energy saving up to 30 percent. However, this requires inexpensive, flexible and easy to handle monitoring and control technologies [26].

Wireless devices support this approach. As they communicate wirelessly and run on batteries or harvest energy from their environment [27], they can be easily installed without wiring, saving effort and cost [28]. This makes them a potential replacement of wired technologies as they can sense building performance data with high precision and accuracy requiring less installation cost. This flexibility makes them especially attractive for energy management in residential buildings, as they allow an easy scaling of the monitoring system size from small size system which is a necessity for residential units.

4.3 Data Warehouse Services

The aim of the data warehouse services [29] of the system is to:

1. Collect dynamic data from different sources such as wired/wireless sensors and meters.
2. Map the dynamic data with data extracted from CAD tools, energy simulation tools and performance specification tools.
3. Perform N-Dimensional data aggregation to support decision making process.
4. Provide information for building users (e.g. building owners, occupants and facility managers) to monitor their current energy consumption.
5. Provide information for preference analysis, predictive analysis and diagnosis to lead to an intelligent building control.

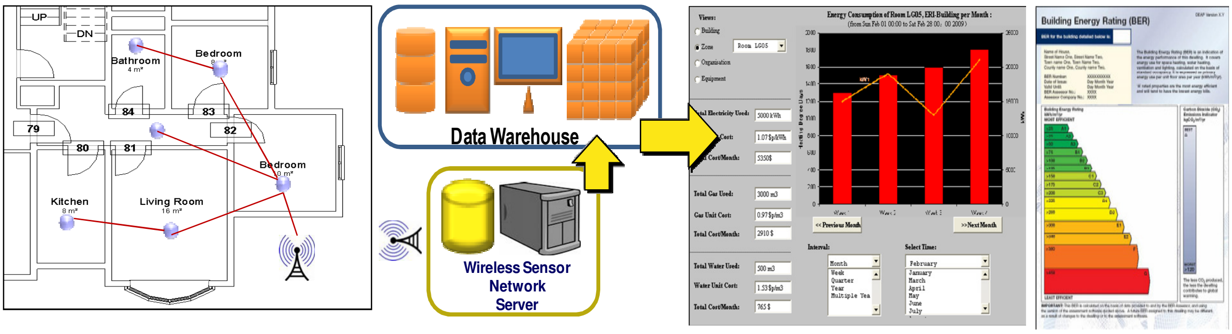


Figure 13: Implementation of Data Warehouse Services

Figure 13 depicts a possible implementation scenario for monitoring and certification of the energy performance of specific apartment blocks. In this scenario, data is collected by the WSN and aggregated by the data warehouse system. Results are represented via touch screen monitors installed within the apartments. Simultaneously, this aggregated information can be used to issue a Building Energy Rating (BER) certificate.

4.4 Possible Energy Saving Improvements

Based on the deployment of a WSN and the information provided by the BIM, results of the case study have demonstrated possible energy saving improvements that can be applied to the existing design of the building. These alterations are discussed in the following paragraph.

Centralised Heating Plant: On large mixed use developments as in our case building the diversity which can be applied to heating is as low as 12-15%. For example if one home required a maximum load of 10kw heating, then 100 homes would only require 120 to 150Kw of central plant, not 1 MW.

Centralised Ventilation: This could be implemented but requires too much vertical ventilation space. Also, ownership and maintenance issues would cause complexities.

Heat Recovery: Air to air heat recovery devices can retain up to 75% of heat. These devices are not as efficient in summer because of the lower temperature difference between internal and external air.

Rainwater Harvesting: Implement water harvesting system, will require an additional water system and may only be feasible for upper floors due to the height to floor area ratio of the building. Also, current rain levels in Istanbul might struggle the feasibility of the system.

Night Purge: This works by allowing cooler night air to naturally enter a space and remove heat from the building. The very heavy thermal mass of the building can be utilised for free cooling of buildings in summer. The construction of the building is already suited to this.

Atrium/Stack Effect: Atria are often used to take advantage of the stack effect. The stack effect takes advantage of natural convection of warm air rising but is limited to certain heights. There is no atria designed in this project and would not be economically viable in a municipality sponsored residential project. Staircases in the building could be used as natural stacks to allow heat to rise throughout the building. However this would make the upper floors too hot for comfort and is likely to cause fire separation problems.

Solar Thermal Heating: On roof and as shades on south facing facades could provide a sizable amount of hot water requirements for domestic washing and cleaning. These panels are economically viable in Ireland in the right circumstances so should also prove useful in Turkey.

Photovoltaic: This could be utilised for electricity generation. In Ireland the capital cost of installation exceeds the useful electricity generated by the panels over their useful lifespan (Approx 20 years). However in Turkey with relatively longer sunshine hours and opportunity to sell the surplus energy back to grid (€28 cent per kwh) these may be feasible.

5 CONCLUSIONS

This paper describes the data representation and aggregation scenario of the “ITOBO” project. The scenario focuses on data collection from a WSN and integrating this with the data extracted from BIM which includes model editors and energy simulation tools.

Data extracted from different information sources are aggregated in a data warehouse core for analysis and represented through GUIs for monitoring and decision support.

Case study demonstrated the potentials of the proposed system in multi-storey residential blocks. Initial results enabled continuous monitoring and analysis of building energy performance and gave ideas for possible energy improvement alterations.

6 REFERENCES

[1] K. Menzel K., M. Kean, M. Keller, C. O'Mathuna, D. Pesch, Toward a Wireless SensorPlatform for Energy Efficient Building Operation, Tsinghua Science & Technology, Volume 8, Number 1, China 2008.

[2] H.U. Gökçe, K.U. Gökçe, D. Browne, K. Menzel, Dynamic System Architecture for Energy Efficient Building Operation: A Case Study of Kiptaş Residential Building, CIB-W78 Conference Proceedings , Istanbul, Turkey, 2009.

[3] ITOBO, http://zuse.ucc.ie. Last accessed 01/06/2009.

[4] Kiptaş, www.kiptas.com.tr. Last accessed on 15/05/2009.

[5] inTUBE, http://www.intube.eu. Last accessed on 01/06/2009.

[6] P. Barrett & D. Baldry, Facility Management Towards Best Practice. Blackwell Publishing. 2003.

[7] PePPu (Performance Based Building), Performance Based Building: Conceptual Framework. PeBBu Final Report, 2001-2005.

[8] US Green Building Council, LEED, Leadership in Energy and Environmental Design Program, 2003. http://www.usgbc.org/LEED/LEED_main.asp.

[9] ICC, Final Draft ICC Performance Code for Buildings and Facilities, International Code Council, Falls Church, VA, August 2000.

[10] US DOE, High Performance Building Metrics Project Framework, US Department of Energy, Washington, DC. 2002. http://www.nrel.gov/buildings/highperformance/metrics/pdfs/framework.pdf.

[11] E. Morrisey, J. O'Donnell, M. Keane, V. Bazjanac, Specification and Implementation of IFC Based Perfromance Metrics to Support Building Life Cycle Assesment of Hybrid Energy Systems, SimBuild 2004, IBPSA-USA, 2004.

[12] D. O'Sullivan, M. Keane, D. Kelliher & R. Hitchcock, Improving Building Operation by Tracking Performance Metrics throughout the Building Lifecycle (BLC). Energy and Buildings Journal, 36:1075-1090, 2004.

[13] J. O'Donnell, Specification of Optimum Holistic Building Environmental and Energy Performance Information to Support Informed Decision Making, PhD Thesis UCC, 2009.

[14] ANSI/ASHRAE (RA99), Standard Methods of Measuring and Expressing Building Energy Performance. Standard 105-1984, 1999.

[15] CIBSE, Guide F: Energy Efficiency in Buildings. CIBSE Publications, 2004.

[16] B. O'Sullivan & M. Keane, Specification of an IFC based Intelligent Graphical User Interface to Support Building Energy Simulation. IBPSA Building Simulation 2005; Montreal, 15-18 August 2005.

[17] Autodesk, www.autodesk.com. Last accessed 01/06/2009.

[18] IES, www.iesve.com. Last accessed on 15/05/2009.

[19] W. Inmon, Building the Data Warehouse, Second Edition, John Wiley & Sons, 1996.

[20] J. Widom, Research Problems in Data Warehousing. International Conference on Information and Knowledge Management; Baltimore, Maryland, 1995.

[21] Amjad Umar, Mobile Computing and Wireless Communications, NGE Solutions, Inc., 2004.

[22] BuildWise, http://zuse.ucc.ie. Last accessed 01/06/2009.

[23] T. Salsbury & R. Diamond. Performance validation and energy analysis of HVAC systems using simulation. Energy and Buildings, vol. 32, no. 1, pp. 5 – 17, 2000.

[24] L. Jagemar, D. Olsson, F. Schmidt, The EPBD and Continuous Commissioning, Project Report, Building EQ, EIE/06/038/SI2 .448300, 2007.

[25] VDMA (German Engineering Federation), Energy-efficiency of Buildings, 2008.

[26] L. Itard, F. Meijer, E. Vrins, H. Hoiting, Building Renovation and Mod-ernisation in Europe:State of the art review. Jan. 2008.

[27] EnOcean Alliance, Energy for free, White paper, 2007.

[28] M. Kintner-Meyer, M. Brambley, T. Carlon & N. Bauman, Wireless sensors: technology and cost-savings for commercial buildings. 2002 ACEEE Summer Study on Energy Efficiency in Buildings, 2002.

[29] H.U. Gökçe., Y. Wang, K.U. Gökçe, K. Menzel, A Data-WareHouse Architecture supporting Energy Management of Buildings, *CIB-W78* Conference Proceedings, Istanbul, Turkey, 2009.