Building Optimisation using Scenario Modeling and Linked Data

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Abstract

As buildings become more complex, it becomes more difficult to manage and operate them effectively. The holistic management and maintenance of facilities is a multi-domain problem encompassing financial accounting, building maintenance, human resources, asset management and code compliance, affecting different stakeholders in different ways. One technique, called scenario modelling, customises data-driven decision support for building managers during building operation. However, current implementations of scenario modeling have been limited to data from Building Management Systems with little interaction with other relevant data sources due to interoperability issues. Linked data helps to overcome interoperability challenges to enable data from multiple domains to be merged into holistic scenario models for different stakeholders of the building. The approach is demonstrated using an owner-occupied office building.

Introduction

The holistic management and maintenance of facilities is a complex problem encompassing financial accounting, building maintenance, human resources, asset management and code compliance, affecting different stakeholders in different ways. The type of information needed by each stakeholder is different and varies in the level of complexity required. The skill-set of each stakeholder is also markedly different and each has very different motivations for accessing information on the building. Navigating through this mass of data in a coherent manner to derive information and tailoring this output to specified end-users is a challenge. Different stakeholders need different views of the information. For example, the Financial Controller is concerned with cost metrics, the Human Resource function is concerned with issues like occupancy patterns, building occupants are primarily concerned with comfort, whilst the owner is motivated by the overall efficiency of the building. There are a variety of measurement methodologies that can be utilized to quantify each of these, but when considered independently, it is difficult to get a complete picture of the building. There is a clear need to define the building's operational strategy in a comprehensive and structured manner with decision support that provides relevant information to stakeholders from each domain.

Decision Support Systems & Building Operation

Unavailable, unreliable, and inaccurate performance information is a major cause of inefficient building operation (O'Donnell 2009). Information used by building managers must be trustworthy, but there are no standards currently available for analyzing and transforming building performance data and information. In addition, current methods and tools fail to account for the profile of building managers, both in terms of the operational context of their role, and their typical technical and educational background (O'Donnell 2009). Building operators tend to lack the level of information necessary to make fully informed decisions and routinely make decisions based on intuition and experience, rather than on quantifiable metrics. Consequently, decisions taken by building managers are often ad-hoc, arbitrary, and incomplete (Neumann and Jacob 2010).

Scenario Modelling

Scenario Modelling allows for the holistic analysis of building performance using quantifiable performance metrics incorporated into a functional model. Scenario modeling enables the explicit and unambiguous coupling of building functions with other pivotal aspects of building operation, see Fig. 1, in a method that specifically considers the education and technical expertise of building managers. This new method captures, transforms, and communicates the complex interdependencies of environmental and energy management in buildings through an easily navigable, holistic, and reproducible checking mechanism that compares actual performance with predicted performance and completes the "plan-do-check- act" cycle for building managers (ISO 2011). Scenario modelling forms the basis for effective decision support for building managers.

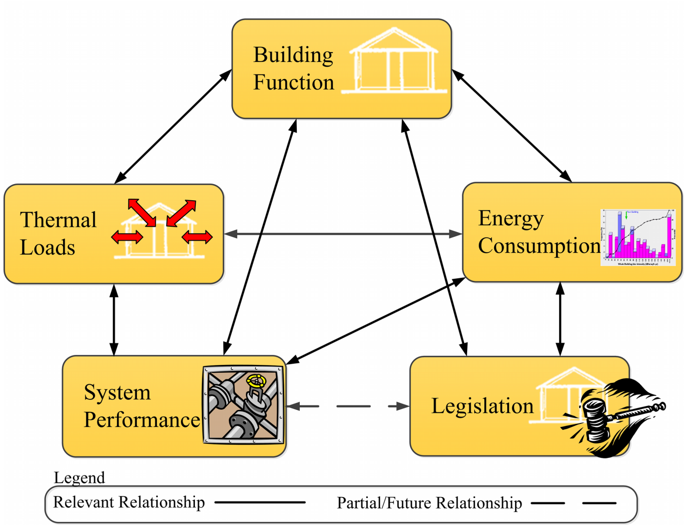

Figure 1: Holistic building performance analysis relies on an understanding of five key performance aspects

The power of this technique lies in the manner a formalised measurement and assessment framework can be created around disparate data sources. However, the lack of informational interoperability has restricted the level of automated evaluation possible for particular performance metrics. The task based nature of the Building Lifecycle (BLC) leads to information being gathered independently several times for specific tasks across various domains. The type of cross domain analysis necessary to drive decision support systems becomes increasingly difficult with a lack of interoperability.

Challenges with Interoperability

Building Information Models (BIM) are a relatively new concept and offer a mechanism through which a complete set of project data can exist in one easily accessible format for building managers (Eastman et al. 2011). However, within the wider-context of the organization a BIM is only one silo of static information, usually captured during the design and construction phase of the BLC. Other relevant information must also be utilized to optimize both the building and organization itself. This information, which may also exist in separate data silos, includes payroll, human resources, production systems, ordering systems, resource-planning systems, etc. Each of these systems may be implemented with different incompatible technologies and data formats, making it difficult to interoperate the data. Due to the critical lack of information interoperability amongst these data silos, it is quite difficult to get a complete cross-domain view of a building (Gallaher et al. 2004).

The open Industry Foundation Classes (IFC) standard promotes interoperability within the building and construction domain, and for BIMs in particular. However, IFC by itself is not sufficient to enable interoperability with systems outside of the Architecture Engineering Construction (AEC) domain, or with systems that are dynamically producing data during the operational phase (i.e. sensor/meters). If powerful decision support solutions like Scenario Modelling are to be implemented a more flexible approach to data interoperability is needed.

Linked Building Data

Semantic Web technologies and standards are playing an important role to simplify the sharing of large quantities of data on the Web based upon W3C standards. The Resource Description Framework (RDF) standard provides a common interoperable format and model for data linking and sharing on the Web. Linked Data is a best practice approach used to expose, share, and connect data on the Web. Linked Data has the following characteristics:

- *Open:* Linked data is accessible through an unlimited variety of applications because it is expressed in open, non-proprietary formats.
- *Modular:* Linked data can be combined (mashed-up) with any other pieces of linked data. No advance planning is required to integrate these data sources as long as they both use linked data standards.
- *Scalable:* It's easy to add and connect more linked data to existing linked data, even when the terms and definitions that are used change over time.

Linked data provides a mechanism through which all silos can exist in a homogeneous format. Most importantly, linked data principles identify common elements between silos, and where possible interlink silos. Representing building data, such as a BIM, within the linked data format, will allow it to be combined with linked data from other relevant silos. In doing so, organizations can generate and extract additional value from current stand-alone repositories, across multiple domains. The resulting merged cross-domain data provides a holistic view of the building's operations, which can have added value for domain stakeholders throughout the organization. Linking building data together can build a holistic view of the building, allowing broader context to be used within scenario modelling decision support. The remainder of this paper briefly describes the approach and demonstrates the concept with an owner-occupied building.

DERI Building Use Case

In order to support the argument for Linking Building Data a proof-of-concept has been developed for the Digital Enterprise Research Institute office building at the National University of Ireland, Galway. The approach was implemented using the Linked dataspace for Energy Intelligence (LEI). This section discusses the LEI system architecture, and a building energy management application built using the resulting linked building data.

Architecture

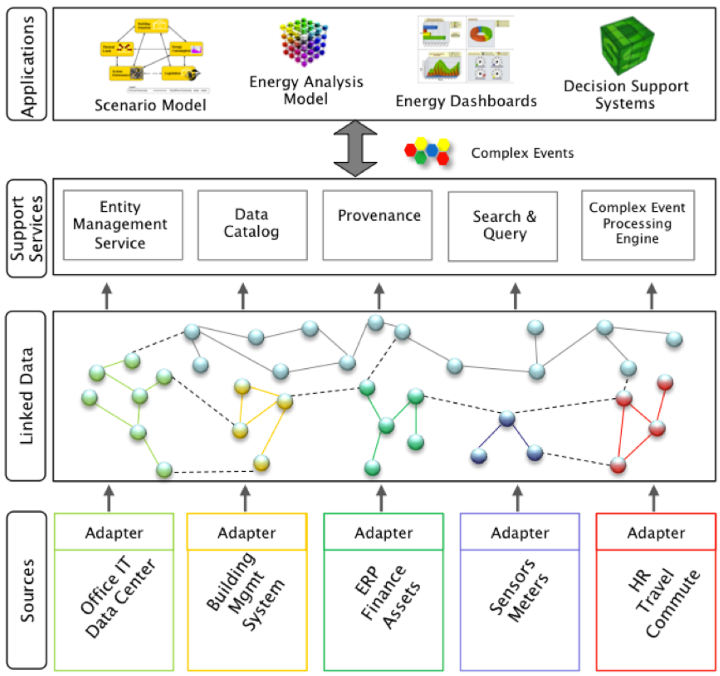

Figure 2: Linked dataspace for Energy Intelligence.

Fig. 2 illustrates the architecture of the OEIP, the main components are:

- *Data Sources:* At the bottom of the architecture are the data sources coming from legacy information systems, as well as sensor networks in the building. There are a variety of data sources from multiple domains. Linked data adapters are used to expose these sources using the linked data principles through the use of unique URIs, RDF, etc.
- *Linked Data Cloud:* The resulting outcome of linked data adapters over data sources is a cloud of interlinked web resources. This linked data cloud is rich with knowledge and semantics about the building, building-related performance indicators, and other contextual data. The linked data cloud forms the basis for real-time building analytics

and other decision support applications with the help of some support services.

- *Support Services:* Developing applications that use the linked data cloud is simplified through the use of support services. Services are available for provenance information (Freitas et al. 2011), entity reconciliation, data curation, retrieval, and discovery of data and data sources. A CEP engine (Hasan et al. 2011) supports real-time aggregation and abstraction over dynamic streams (i.e. energy sensors) in the linked data cloud.
- *Applications Analytics:* At the top of the architecture are a range of applications and analytics built using the linked data cloud. Within DERI a number of applications utilize the linked data cloud including, data center energy management (Curry et al. 2012), IT-energy management, and personal energy management. A Building Energy Explorer application was also developed.

Building Energy Explorer

The Building Energy Explorer allows users to understand the cause and effect of energy consumption within the DERI building. The objective of the explorer is to help users identify energy leaks and non-ecological actions within the DERI building. The explorer makes extensive use of the merged data within the linked data cloud (i.e. people, projects, teams, building layout, etc) and combines it with energy consumption sensor data. It then presents it in an actionable manner that requires minimal effort for users to leverage within energy-related decision-making.

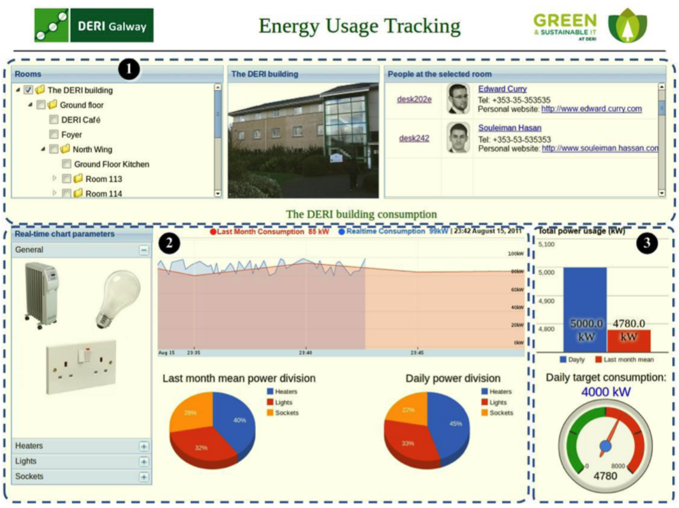

Figure 3: Facilities energy tracking dashboard.

The main screen of the dashboard is presented in Fig. 3, within box (1) data from rooms, people, and groups can be seen; it is used to add context to the energy consumptions readings. In (2) historical usage along with real-time instant measures from the energy sensors are shown, along with a breakout for consumption type (lights, heat, sockets). The interface also displays the output of the Energy Situation Awareness Service via a widget in (3). The service is based on a scenario model to perform energy situation assessment by comparing the accumulative consumption with historical usage data, and usage targets, to detect high usage situations. In the widget, two bars are shown aside to show the daily-accumulated energy usage in comparison with the monthly average which gives an idea about the amount of deviation in the consumption pattern. Other scenarios can be easily defined based on different performance criteria including cost, occupancy comfort, and average energy usage per occupant.

Conclusions

The combination of Scenario Modelling and Linked Data offers a promising approach for the design of building decision support systems. Scenario modelling helps buildings operators to understand the complex interdependencies of environmental and energy data in buildings. Linked data overcomes interoperability challenges to enable data from multiple domains to be merged into holistic views for stakeholders of the building. The approach was demonstrated within a proof-of-concept in an owner-occupied building. Future research will focus on the definition of more complex scenario models and a user evaluation of the resulting decision support applications.

Acknowledgments

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