USABILITY EVALUATION OF AN ACTIVITY MODELLING TOOL FOR IMPROVING ACCURACY OF PREDICTIVE ENERGY SIMULATIONS

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ABSTRACT

This paper presents an evaluation of the level of usability of a web-based tool for rapidly capturing building occupant activities. This data supplements the building knowledge-base, which can be theoretically used to improve the energy efficiency of the building. The interface makes use of Linked Data (LD) and an integrated ontology for managing building data relevant to building energy consumption. The ontology is based upon building information modelling (BIM) standard Industry Foundation Classes (IFC) to support its integration into a wide set of commercial tools, in particular those related to energy simulation.

INTRODUCTION

Taking into account the whole Building Life Cycle (BLC), which defines the entire life of a building from design, through operation and on to eventual demolition/recycling (Smith and Tardif 2012), buildings are responsible for around 40% of total EU energy consumption (Balaras et al. 2007). The EU has established the Energy Performance of Buildings Directive (EPBD), which by 2019 requires public buildings to consume zero energy and look to contribute energy savings. New strategies to reduce energy consumption during the operational phase of the BLC are a necessary step to achieve this goal.

Building Automation/Control Systems (hereafter referred to as BAS) are a technology to maintain or improve user comfort and improve energy efficiency by controlling different building facilities (HVAC, lighting etc.). Energy usage is strongly influenced by the operation and utilization of the different spaces (Hoes et al. 2009) and the activities of occupants (Agarwal et al. 2010). BAS can make use of activity models, like occupant schedules, to control when devices turn on and off. BAS may also support automation through detection of activities using sensors, for example, PIR (passive infrared), CO2, ultrasound, cameras, and/or tag based system, like RFID, Bluetooth and Ultra Wide band (Timilehin et al. 2015). When running predictive energy simulations, the knowledge derived from such systems can provide a more accurate representation of the occupant behaviour than models which rely on generic patterns, like those of many modern energy simulators (Paola, Ortolani, and Re 2014). Unfortunately, these technologies have associated risks. Some modern BAS require the occupant to carry a tag, or other type of transmitter, which can result in unrealistic situations and errors, for example, when left at a desk or uncharged (Timilehin et al. 2015). Transmitter signals are also subject to signal degradation due to building geometry, materials and objects/devices, making the cost/benefit of installing such systems, which provide varying levels of accuracy, questionable (Timilehin et al. 2015). A common issue of all commercial BAS is their limitation to detect complex activities (PIR/ultrasound) and/or occupant's monitoring (PIR/CO2 sensors). To overcome this latter aspect, reasoning and sensor fusion can be used to make inferences about more complex behaviours, but as yet, such systems are not commercially available (Timilehin et al. 2015).

In this paper, we present a novel method for engaging building users with the process of recording their activities by presenting them with a web-based activity modelling tool to record how they use the building during a typical week. This provides data in the form of usage schedules for each occupant, without the need for new sensor installations. User provided schedules have been shown to provide more accurate inputs into predictive energy simulations (Goldstein, Tessier, and Khan 2010). By making the process simple to use, users can provide regular updates about how they use the building, iteratively adding to a growing building knowledge base. The tool is part of a wider tool set for building operational energy management, which makes use of the knowledge base to control building behaviour. Therefore, the proposed solution combines building information modelling standards (industry foundation classes) with semantic web technologies (linked data) to ensure data accessibility across the BLC. The level of usability of the method is evaluated, as this is a key determining factor for its success.

REQUIREMENTS AND DESIGN

The web-based activity modelling tool has been developed after analysing five public buildings in Europe (Netherlands and Spain), conducted under the KnoHolEM EU project. The five buildings are the Forum building in Eersel, the Haagse Hogeschool in the Hague, the Media-TIC in Barcelona and finally the BlueNET and PICA buildings, both in Seville. Each have a range in types of users, architectural layouts, seasonal energy demands and heterogeneity of BASs. The requirements gathering began with analysis of existing building data and models (e.g. CAD models). Site visits were then conducted for each building object. These included interviews with each buildings Facility Manager (FM). The FMs were queried about how they record user behaviour and whether activity models for occupants exist. From the site interviews and analysis of the building models it was discovered that there was a distinct lack in activity models for the building occupants.

Where these models exist they tended to be generic for all occupants, indicating only the working hours of occupants over the whole building. Some of the buildings had CO2 sensors to determine presence (HHS) and also motion detectors for turning on and off lighting (HHS, Media-Tic and Forum). The CO2 sensors simply alert the HVAC units that a room is occupied using a threshold for CO2 levels, and therefore cannot give any accurate indications of numbers of persons in an area/zone. The motion detectors could also not give a reliable count as to the number of persons that have passed, as they are a simple on/off trigger which, without additional reasoning capabilities, could not be used to determine direction or number. It was concluded that in the absence of the installation of an upgraded sensor network for more fine grained occupancy detection (e.g. number of occupants in a zone/area), FM's are required to use fixed generic schedules to control the building systems (HVAC and lighting) based upon their own analysis of the buildings usage. Likewise, energy modellers who wish to model the energy consumption of the building are left to base their occupancy models on input by the FM, or the simplified occupancy models. Therefore, a method by which occupants could contribute to an integrated building knowledge-base by modelling of their own activities was seen as a potential solution which does not require the monetary and logistical costs of installing new sensors.

This type of data integration requires consideration of the underlying data models and their representation. BIM describes an integrated approach to data modelling for storing all information relevant to the BLC. This can include a 3D model of an architectural design, and the building facilities (including sensors). Collectively this data can be used for visualisation and simulation of the building throughout the BLC (Popov et al. 2010). Furthermore, the Architecture, Engineering and Construction (AEC) community has elaborated the IFC. IFC is an open, freely available, non-proprietary data model which can be used to exchange and share BIM data in a standardised way. In practice, IFC has yet to make a significant impact in the AEC communities (Eastman et al. 2010). A major issue is the complexity of developing full BIM (Howard and Björk 2008) capable of combining 3D models for visualization with continous flows of data and external energy modelling tools (Smith and Tardif 2012).

Modelling all this data in a consistent manner requires considerable effort. Methods which simplify uplifting data into a structure which can be made accessible, whilst also providing links to other data sources (product costs, energy tarifs, weather data) is preferable over using proprietary data silos, each with their own API to access data. Linked Data offer a potential solution in terms of exposing, sharing, and connecting data within the web. LD architectues are based on Resource Description Framework (RDF) as a data model for representing structured content. Commonly, data is queried using SPARQL end-points. Thus, data in LD can be navigated in a similar way as navigating through HTML hyperlinks using a web browser. Therefore, the combination of IFC and LD has the potential to meet the requirements for storing and sharing BLC data. The web-based activity modelling tool uses LD for storing generated activity data. The previous analysis therefore resulted in the following three high level requirements for the proposed Activity Modelling Tool, that it be: (i) **R1**: Usable by building occupants so that they can provide inputs on their activities within the building. (ii) **R2**: Flexible and scalable, so that it can be quickly deployed in new buildings with minimum costs associated. (iii) **R3**: Integrated with BIM and the building knowledge-base, so that the provided data can be accessed and used by relevant parties (e.g. FMs, energy simulation experts). In the following sections we describe the design of the tool to meet these three high level requirements.

Activity Model Design

The activity model is required to support the building occupant in the task of contributing to the knowledge-base through the web-based tool. This data is then used to support energy simulations and also the BCS. The activity model is built upon an existing model developed by Tabak (Tabak and de Vries 2010). **Figure 1** shows a class diagram of the model. It has three main concepts; these are a **Zone**, an **Activity** and an **Actor**. Zone and Actor have direct mappings into the IFC standard, as ifcZone and ifcActor. An Activity has properties such as start time (a date and time when the activity commences), duration, and type and has associated instances, actor, zone and path to and from.

Activities include both scheduled (skeleton) and interrupt (intermediate) activities. Scheduled activities work purely according to the start and end time. Interrupt activities can occur according to probabilistic models to capture the unpredictability of its occurrence, which is increased in relation to its frequency (Tabak and de Vries 2010). The Activities are defined and managed by the Actors, and range from generic (e.g "*going to the bathroom*") to specific activities (e.g "*desk work*"). Furthermore, the actor is able to define their personal comfort preference that the system will take into account. Actors can also define holidays. When an Actor defines an Activity, it is associated with a specific Zone so that occupants

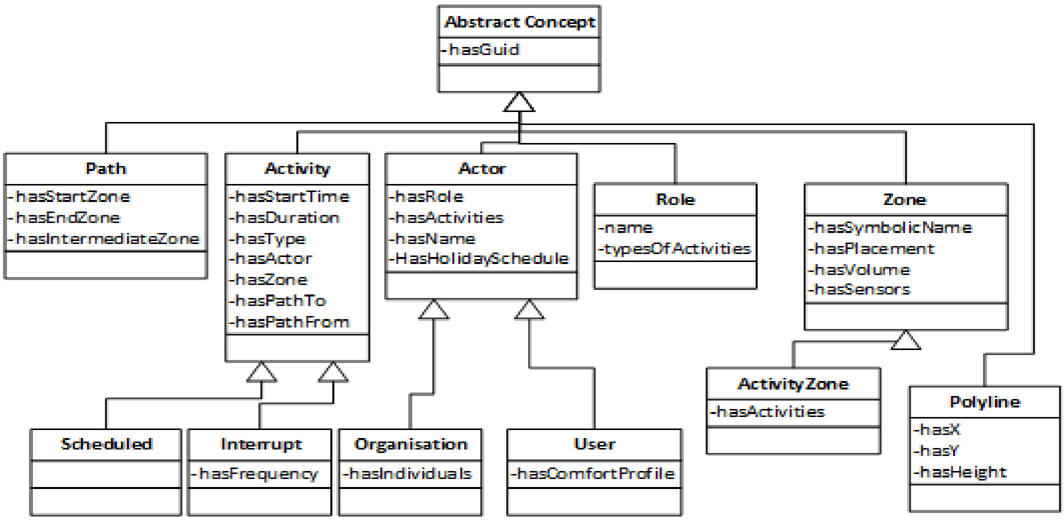


Figure 1 Web Based Tool Class Diagram

can relate their activities with particular zones in the building. Zones are visualised within a representation of the building floor plan. This requires at least a 2D model. A “Polyline” is used to capture this, which has two data property relationships ‘hasXCoordinate’, ‘hasYCoordinate’ and ‘hasHeight’ (a polyline may be projected into ‘3D’ using a height property). This model can be easily extended through the use of new relationships, for example, ‘hasMaterial’ or ‘hasThickness’, or other IFC related concepts. A mapping may also be made between polyline and a ‘Wall’ (ifcWall) concept, for example, ‘isAWall’. In this way, the visualisation model can be quickly related to other concepts for describing properties relevant to other aspects of energy management.

This simplified method for representing the building geometry is a result of findings during the building analysis, which discovered that while the five buildings all had 2D CAD blueprints (dwg), only two (at the beginning of the project) had 3D Google SketchUp models, and were these were provided they either covered only particular areas of the building (HHS) or they only contained the external walls and windows of the building (the Forum). It was assumed then, that many public buildings would not have 3D models defined, and as such, to support **R2** a scalable method to rapidly construct a 3D graphics model was required. Our solution therefore requires an existing 2D CAD model (dwg) that can be parsed into a usable data format.

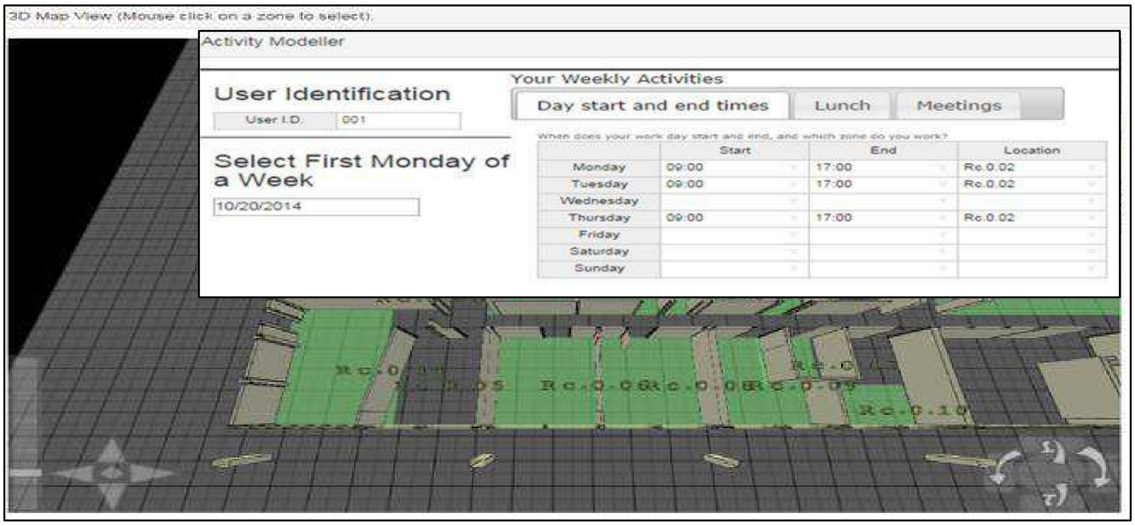
Energy Simulation

Energy simulation tools typically utilise user defined start and end times for a building or zone with an occupant density ratio (e.g. persons/m^2). At early design stage, such information is limited in detail and pre-defined occupant densities are chosen that are broadly reflective of a zone type such as waiting rooms, lecture halls or open plan offices, these types can be taken from the UK’s NCM Activity database for example. These values tend to have been built up by limited on site research and rely on rules of thumb but are the best available starting point for design simulations and their certification. It is unlikely that anything more than a generic, pre-definition of occupancy could be used for a design stage energy simulation, however use of occupant data gathered via the activity modelling tool for multiple buildings could be aggregated to provide more robust estimates of occupancy for each zone “type” such as in the examples given above.

These initial estimates are important as they apply the associated occupant heat gain to the space (both sensible and latent heat) and in so doing through a heat balance equation aid prediction of the heating or cooling required to that space. However, aligned energy prediction calculations can also be linked to this occupant schedule and density, such as a consumption rates for small power (office equipment), domestic hot water and lighting fitted with occupant detection (PIR). Naturally, any error in the estimates will lead to error in the prediction. However, the tool’s key improvement on current practice comes into play with the re-simulation of occupied buildings (due to major refurbishment or other requirement) – theoretically a much more achievable proposition in the future as all the required inputs for the thermal simulation are held within the BIM data for that building. The building-specific occupant density and schedules provided for each zone (where sufficient respondent numbers allow via the interface) will now remove one element of estimation from the energy simulation and in so doing should narrow the gap found between the initial energy consumption prediction and rates of consumption found in use.

IMPLEMENTATION

This section is divided into three parts. The first part discusses how the underlying data is structured, stored and accessed by the activity modelling tool. The second section looks at how the building and zones are visualised. The third section details the prototype tool. This is evaluated in the summative evaluation in the next section.


3D Map View (Mouse click on a zone to select).

Activity Modeller

User Identification

User I.D. 001

Select First Monday of a Week

10/20/2014

Your Weekly Activities

When does your work day start and end, and which zone do you work?

	Start	End	Location
Monday	09:00	17:00	Rc.0.02
Tuesday	09:00	17:00	Rc.0.02
Wednesday			
Thursday	09:00	17:00	Rc.0.02
Friday			
Saturday			
Sunday			

Figure 2 Activity Modeller with WebGL View (Forum Building)

Building Data Management

The class diagram in **Figure 1** has been converted into OWL (Ontology Web Language) using Protégé. OWL is built on RDF and allows for greater expressivity for relationships (McGuinness and Van Harmelen 2004). With Protégé, OWL ontologies can be modelled and extended through new concepts and relations. While OWL also supports other capabilities, such as reasoning, the advantage of OWL for the web based tool is it extensibility. Data is stored using RDF triples making it publishable on the web, and using a URI, can be queried over HTTP. An RDF triple describes data in the form subject, predicate and object. For example: “ScheduledActivity ‘A’ hasZoneID ‘1’” or “Polyline ‘p’ hasXCoordinate ‘10’”. In this way all the data requirements of the activity modelling tool are stored as RDF. Once the ontology is defined, along with concepts and relationships, our solution then makes use of the Fuseki SPARQL server to store the RDF data. SPARQL is a query language for querying RDF triples. Fuseki provides REST-style updates over HTTP, allowing both queries and updates.

Building and Zone Visualisation

For web based geometry visualisation the existing 2D DWG file is parsed and converted directly into RDFand stored on the Fuseki server. WebGL is used for visualising the building geometry. WebGL is a JavaScript (JS) graphics library for doing 3D graphics on a web browser (Parisi 2012). **Figure 2** depicts the resulting 3D model as presented through the browser. WebGL supports functionalities like control of the camera view, point and click selection of objects among others. The geometry data need only be queried once from the Fuseki server, at which point it can be stored client side (on the host machine), thus reducing traffic between the server and the client. Any changes to the building geometry model through the interface need only update the particular individual in the triple store, for example, to create or delete a zone. AJAX is used to handle communication between the client and the Fuseki server.

Activity Modelling Interface

The Activity Modelling interface integrates the WebGL visualisation and is implemented using HTML5 and CSS. The main page makes use of an open source front end framework called Bootstrap, which is particularly suitable for developing web pages which will work on desktops and mobile devices. Bootstrap offers functionality to divide the page using an ‘accordion’ which can be clicked on to reveal or hide the content of a panel. Hence, the Bootstrap visualization has been subdivided into two main parts: 3D Map View and Activity Modeller (overlaid in **Figure 2**). The 3D Map View represents geometry in 3D. The Activity Modeller is modelled by using an open source library called “*Handsontables*”. This supports entering activities over a week, achieved by entering in the start and end times of each working day, lunch, meetings and other relevant activities as well as their location. These activities are then stored in the Fuseki RDF server and can be then exported to the appropriate energy simulation tool for developing more accurate simulations.

EVALUATION

Evaluation Methodology

The methodology for evaluating the tools consists of both formative and summative evaluations (McGlinn, Hederman, and Lewis 2013). The formative evaluations are conducted during the early development to mould or improve a product. Outputs of formative evaluations may include participant comments (attitude’s, sources of confusion, and reasons for actions) and other discovered usability problems and suggested fixes. In contrast, summative evaluations are carried out at the end of development. They set out to measure or validate usability by comparing usable metrics and generating data to support claims about usability. Outputs of summative evaluations may include statistical measures of usability, for example success rate, average time to complete tasks, number of errors/assists.

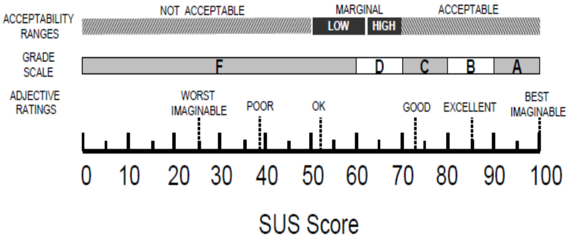


Figure 3 A comparison of the adjective ratings, acceptability scores, in relation to the average SUS score (Bangor, Kortum et al. 2009)

The evaluations are structured upon Common Industry Format (CIF). A CIF usability report must include; a description of the product/model, the goals of the test, the test participants, their background and the tasks they are to perform, the method by which the test was conducted, the experimental design of the test, the usability measures and the numeric results and analysis (Bevan 1999). The metrics of the evaluation are taken from Sauro and Kindlund, who have created a quantitative model of usability based upon the ISO 9241 standard, resulting in four metrics (Sauro and Kindlund 2005). These are time to complete tasks, number of errors, whether a task is completed and the average satisfaction of users. User satisfaction is measured by using the System Usability Scale (SUS). SUS is a simple ten item scale giving a global view of subjective assessment of usability. The statements in SUS are chosen to identify extreme expressions or attitudes. SUS also provides a point structure to assign to the answers of a particular test which rates overall satisfaction between 0 and 100. Bangor and Kortum suggest that a score in the seventies should be deemed acceptable, and those below still have usability issues of concern. With respect to the number of participants required to find all potential problems, this may vary according to the users, the tasks, and the system under test. At least a range between five and fifteen is required to evaluate sensitive parameters as depicted in (Nielsen 1994) (Woolrych and Cockton 2001).

Formative Evaluations: Goal, Participants and Backgrounds

The goal of the initial experiments were to assess the level of usability of the BuildVis tool for occupants, in particular with respect to errors, when entering in daily activities for the period of one week in the Forum and BlueNet buildings. Two informative evaluations took place. The first was in the Forum building with 7 occupants (doctors, each with private office spaces). The second evaluation took place in the BlueNet building in Seville, were 25 occupants took part. These were office workers, located in a mix of open plan offices and single offices. For the initial evaluations, no pre or post questionnaires were used. People were sent the interface and when an error occurred they were to contact the person responsible for distributing the interface, communicating with the participants and who would report to us to identify the error and correct it (hereafter called the ‘distributor’).

Formative Evaluations: Experimental Description and Tasks Description.

The participating occupants were each sent an e-mail by the distributor. The e-mail contained a link to ethical forms and to an information sheet with the tasks. These are given in both Dutch and Spanish for the respective buildings. The task for the Forum building users required them to enter in a unique id number, select the zones in the office space where they spent their work day, input their start and end times of the day, input the start and end time of their lunch break and its location, where they took breaks (coffee, water, toilet) and how frequently, and finally the start and end time of meetings, and their location. Locations of meetings, lunch and breaks which took place outside the building, were indicated simply as ‘Outside’ in the interface. They were also to indicate which entrances they used, indicated by coloured zones.

Formative Evaluations: Technologies

The initial formative evaluation made use of an open source jQuery library called “*Handsontables*” which provides an ‘excel like’ tabular form for entering in activities. For the Forum building, the WebGL interface had not been implemented and only a PNG image was available of the floor plan, with zones added. The interface communicated with the Fuseki server and updated activities directly into the building specific ontology using SPARQL. For the BlueNet building the WebGL interface was tested.

Formative Evaluations: Findings, Interpretation and Conclusion

Only one of the seven doctors managed to complete the tasks on their own. The other doctors were unable to complete the tasks and were required to contact the distributor for assistance, who then sat with them and they entered the data together. The distributor identified a probable cause for the high error rate among doctors (i.e. all but one requested help); that the doctors are busy and also have schedules which are not fixed as they could leave at any time on call. Therefore, they may not have felt that any input they gave was accurate and thus requested help. The distributor advised them to enter in activities for the current week regardless of whether it was similar for the previous weeks, as part of an iterative process to build up an occupation pattern.

For the BlueNet building users the WebGL viewer resulted in a new issue around a font library created for text display. This did not display correctly on Macs, which the users had been advised not to use, but had nonetheless. Another issue was also identified related to the manner in which times are entered into the “*Handsontables*” interface. To align the data with the energy simulators, the participants were asked that times be entered on a half hourly basis. While the pre-set values adhered to this, it was possible for the user to enter in any time they wish using the interface. These values were not updated correctly in the RDF store, and this data was therefore lost. The number of significant errors for the evaluation was therefore high. Other issues around the tools complexity were also highlighted, for example requiring participants to enter in details about the frequency of certain types of breaks is a time consuming process.

Due to the irregular scheduling of doctors and the number of significant errors (i.e. requiring help from the distributor), it was concluded that it may not be appropriate for doctors. This is because, even if they were capable of entering in their activities, it would need to be on a regular basis to determine any reliable patterns to behaviour. This may not be realistic considering their busy schedules. From the correctly inputted data gathered from the BlueNet participants, it was apparent they had more predictable usage of the building. It was therefore concluded that the tool, as it is implemented, is more suitable for this type of building occupant. The tools complexity was also reduced in the next evaluation by simplifying and reducing the tasks, and the technical issues were addressed.

Summative Evaluation: Goal, Participants and Backgrounds

The goal of the final experiments was to assess the level of usability of the BuildVis tool for occupants, with respect to errors and SUS scores, when entering in daily activities for the period of one week in the Media-TIC buildings. The summative evaluation examined office workers, this time within the BDigital offices in the Media-TIC. 13 were available to conduct the final summative evaluation. As the web based tool is used through the browser and in order to identify any issues that may be related to the particular browser (Chrome), a short pre-questionnaire quizzed them regarding the type of browser they used and how often they used it. In this offices most occupants uses the browser daily. Furthermore, results demonstrate that three of the participants don’t feel confident using their browser.

Summative Evaluation: Experimental Description, Tasks Description and Technologies Used.

These tasks were given in Spanish and differed from the previous set of tasks only in that they need not enter breaks and frequency of breaks. The WebGL interface also allowed them to now select a zone through the interface. An additional jQuery library was also used to support selection of date and time.

Summative Evaluation: Findings

All participants completed the assigned tasks. Of the 13 that were evaluated, we know of 4 participants who had to contact the distributor, by e-mail, to solve specific issues. Once the pre-established task were performed, the building users were required to complete the SUS questionnaire. **Figure 4** gives a breakdown of the user responses. The SUS give a total score of **59.8**. Looking further at the questions we see that the majority of users agree that the system is easy to use (seven versus two) and that they would imagine most people would learn to use the system very quickly (ten agreeing), although, there were three polar responses on this response, two strongly agreeing and one strongly disagreeing. The majority also agreed that the system was not cumbersome to use, the functions were well integrated and that there was not too much inconsistency in the system.

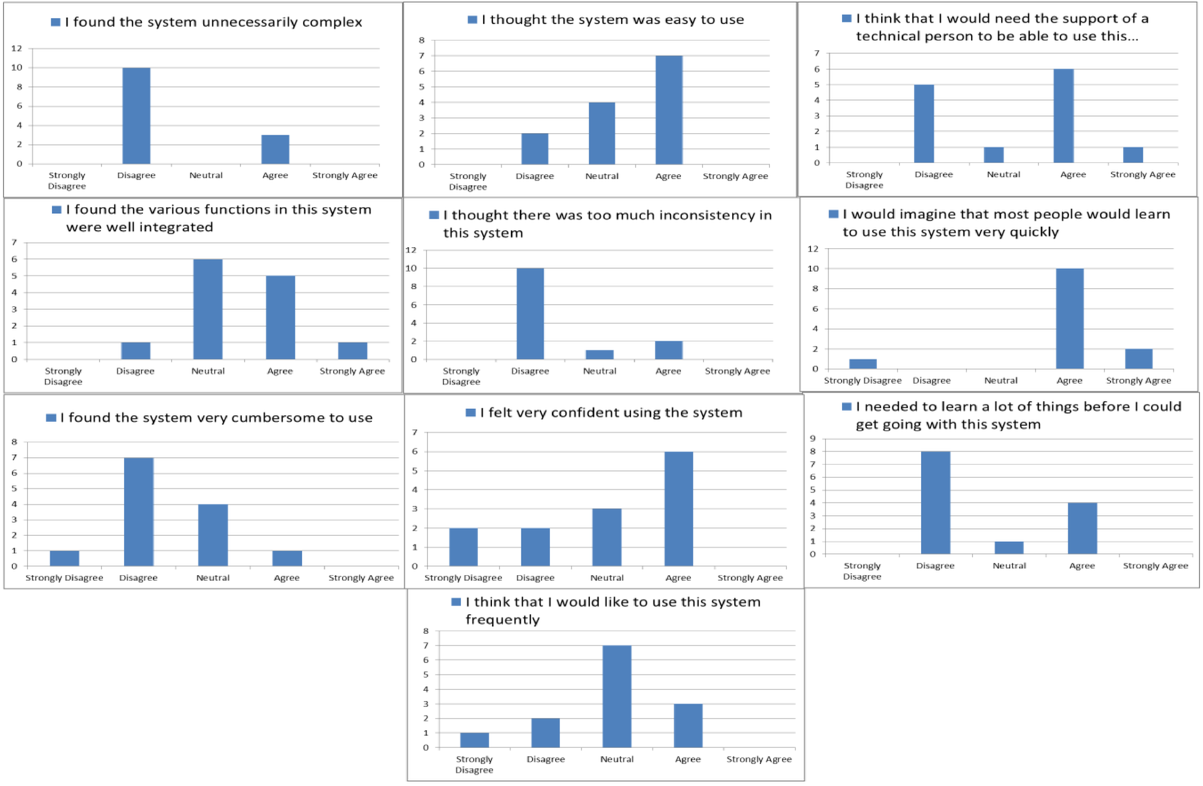


Figure 4 Break Down of SUS Responses

Three additional follow up questions were provided. These were; Would you like to see additional features (give the features)? What features of the tool, if any, did you like? What features of the tool, if any, did you dislike? Here we provide the most relevant answers (spelling errors corrected). To the first question three replies stand out as being relevant. These were 'I would like an integration with eMail calendars to import the meetings and daily tasks.', 'maybe a wizard-style information introduction' and 'For people with a strong routine, it would be useful to have the ability to duplicate the timetable entries throughout the week.' To the second question entries included: 'I like the 3D representation of the building', 'The grid for entering the data', '3D map helps the user to indicate his location' and 'Map Interaction'. To the final question there were three criticisms we felt were worth noting: 'It was not possible to enter the exact data, you had to confirm with the options given.', 'The control of the map is complex', 'The 3D model of the work place doesn't give any extra information for the intended use than a 2D representation of it.'

Summative Evaluation: Conclusion

The final summative evaluation of the BuildVis Activity modeller revealed some important findings regarding the levels of usability of the tool and requirement **R1**. The SUS score of **59.8** indicates that changes are still required to improve its usability and highlights the considerable challenges related to getting office workers to become active participants in the energy management of the building. Even after simplifying the interface to make it easier for occupants to input data, there were still many issues for office workers. A number of methods can be employed to ameliorate these issues. Some of these may simply be the method by which users are trained to use it. For example, a more interactive instruction menu would certainly go some way to improving the error rate. Another option may be to provide a graphical interface to select start and end times of days, perhaps using sliders.

Overall Conclusion and Future Work

This paper presented a web-based tool for entering activities related to building usage to supplement existing knowledge on building occupant usage. This data is intended to be integrated with energy simulations, to improve energy prediction. It has been evaluated against three main requirements **R1** (usability), **R2** (flexibility and scalability) and **R3** (integrated data model). With respect to **R2** the tool has been deployed in 3 buildings, and has now been demonstrated to work on a range of browsers (Firefox, chrome, IE) and operating systems (Linux, Windows), demonstrating its flexibility. The ability to scale to other buildings therefore is simply a matter of converting a 2D DWG, adding zones and then sending the URL to the occupants. With respect to **R3**, the underlying models are, where possible, based upon existing building standards (IFC), thus facilitating integration with tools which support IFC. The use of RDF and OWL make the data publishable on the web, which can then be integrate with other relevant data sources, which using SPARQL, can be accessed by any product/service which supports this technology.

R1 requires additional design and evaluations cycles before it can be said that the tool is suitably usable. Nonetheless, the Activity Modeller begins a dialogue between the office workers and the building energy management through the process of modelling their use of the office space. Future versions of the Activity Modeller will also look to link the capabilities to annotate on the 3D map (e.g. locations which they work, eat, etc.) in a manner which improves the usability of editing. Furthermore, visualisations indicating energy consumption will also be integrated, and aligned with behaviour. Ideally this will form part of the user's online profile, in a similar manner to a Facebook or Google+ account. Towards this goal work has begun on examining links to online profiles like Google+. A new feature has been enabled to support importing Google calendar events directly in the meetings table of activities in the interface. This will both reduce the complexity of adding new meetings, but also begins to bridge the gap between our tool and a user's online identity. This online identity may also reveal details about their movement beyond and between buildings. We believe such a tool, integrated with visualisation of energy consumption and costs, can become a useful addition to a person's capability to manage their energy consumption both at home, and also in the work place. Such feedback would make the benefits of the tool much more apparent, and perhaps increase the willingness of users to enter in their activity profiles and provide information regarding their behaviour.

It should also be noted that the activity models have been integrated with an energy simulator (Energyplus). Due to the number of available simulation tools, no direct communication between the activity modeller and EnergyPlus was developed. Instead a simulation expert took the activity models and used them as inputs into the simulation software by hand. As we are dealing with tabular data, next we will begin to develop mappings to the different proprietary formats as required, and make them accessible over the web. The use of "*CSV-LD*" has been considered for this purpose.

The Activity Modelling tool presented here is part of a larger integrated tool set called the 'BuildVis tool'. Based on the same technologies and underlying data models, it provides additional capabilities as a monitoring and action suggestion tool for Facility Managers, by providing feedback on the historical and current building energy consumption and by providing generated suggestions (based on a range of inputs, including occupational patterns) on how to configure the building system to improve energy consumption. This has been developed as part of the KnoHolEM project and results of the usability evaluation of these capabilities are to also be published shortly.

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