Method comparison analysis of dwellings' temperatures in the UK

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Amoako-Attah and B-Jahromi

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1 **Joseph Amoako-Attah** MBA, MSc
Doctoral candidate/Lecturer, Department of the Built Environment, School of Computing and Technology, University of West London, London, UK

2 **Ali B-Jahromi** MSc, PhD, CEng, MICE
Associate Professor in Civil Engineering and Course Leader, Department of the Built Environment, School of Computing and Technology, University of West London, London, UK


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The credibility and confidence in usage of a simulation program must be underpinned by an acceptably robust validation process. Over the years, various techniques have been employed to validate thermal simulation programs of buildings to facilitate continuous improvement of software development and acceptability. This study introduces the Bland–Altman method comparison analysis as a simulation validation tool to statistically evaluate the agreement between monitored temperatures and predicted thermal analysis simulated operating temperatures of detached dwellings in the UK. The findings of this work give the indication that there is very strong agreement between the monitored temperatures and the thermal simulation analysis results.

1. Introduction

The UK Building Regulations with their continuous emphasis on improvement of building requirements is influencing the building industry towards the achievement of the set UK Climate Change Act target of reducing greenhouse emissions by 80% in relation to 1990 emission levels by the year 2050 (Amoako-Attah and B-Jahromi, 2013; Climate Change Act 2008). Professionals in the built environment are increasingly accepting building energy simulation as the status quo to drive the design of more energy-efficient buildings (Witte *et al.*, 2001), not only to meet the government set targets but to delight consumers in general with accurate prediction of energy performance in dwellings. However, accurate modelling and simulation of energy flows in buildings to reflect their actual thermal behaviour of temperatures, envelope losses, system performance and electrical loads (Judkoff *et al.*, 2008) is still a challenge, as numerous assumptions are made on the impact of uncertainties relating to a large number of building parameters. Moreover, recent studies have shown an insignificant correlation between design stage and actual energy consumption in buildings (Cibse, 2013; Hogg and Botten, 2012). It is therefore obligatory continually to seek for validation techniques, not only to inspire confidence and reliability in building simulation programs but also to facilitate a process of continuous improvement in the development of these software programs.

Building energy modelling and simulation programs have been used to evaluate building performances and assessments in the areas of: building design and regulatory compliance; evaluation of changing weather data for an overheating analysis; assessment of building internal conditions (infiltration, ventilation, lightning gain, occupancy sensible and latent, equipment sensible and latent, and pollution generation); evaluation and enhancement of building thermal mass; evaluation and selection of renewable energy sources; building automation systems; and moisture phenomena (Amoako-Attah and B-Jahromi, 2013) – and there are scores of building simulation programs to undertake these tasks. The accuracy of building energy simulation has a direct bearing on the meticulous selection of the simulation input data (Judkoff *et al.*, 2008). While there are no perfect modelling and simulation input data, these uncertainty parameters have to be analysed to determine their adequate values to reduce sources of discrepancy with the aim of reaching optimum design solutions of improving building performance indicators and contributing to the overall effort of greenhouse emission reduction.

In general, although there have been various validation studies undertaken in the use of some of these building simulation programs, there exists no explicit systematic development of validation methodology for such programs (Judkoff *et al.*, 2008). Current validation techniques broadly include comparative studies, analytical verification and empirical validation (Judkoff *et al.*, 2008). There exists valuable technical information to help in the assessment and analysis of simulation programs. For example, the thermal analysis simulation software, TAS, used in this work has been validated through analytic verifications, intermodal comparison and experimental validation (EDSL, 2014).

The aim of this work is to provide the Bland–Altman method as a method comparison statistical study of agreement analysis between monitored temperatures and thermal analysis simulated operating temperatures of detached dwellings using an approved thermal analysis building simulator. Investigations related to the use of the Bland–Altman procedure for method comparison permeate clinical studies. For instance in 2003, Bland and Altman used the limits of agreement approach to analyse two different methods of measurement of single X-ray absorptiometry and single photon absorptiometry (Bland and Altman, 2003). In the same year, Lu *et al.* (2003) presented a study that validated a bio-impedance analysis system by comparing it with dual-energy X-ray absorptiometry in assessing body composition in obese children. Later, Brazdzionyte and Macas (2007) used the Bland–Altman graphical technique to evaluate the hemodynamics in patients with acute myocardial infarction using the two methods of intermittent thermodilution and impedance cardiography, and then van Stralen *et al.* (2012) using the same approach carried out work on two different blood pressure devices. To the best of the present authors' knowledge, Bland–Altman's method of statistical agreement evaluation has not yet been applied to the validation of building energy simulation.

Moreover, the statistical coefficients of mean bias error, root mean square error and the coefficient of variation of root mean squared error presented in the Ashrae Guideline-14 (Ashrae, 2002) is done in the context of estimating building simulation model accuracy to that of actual energy consumption. Georgiou *et al.* (2014) noted that 'currently, there is not any metric, which evaluates the space temperature' and therefore used a graphical approach in their work on modelling indoor temperature. In the same vein, this work focuses on method comparison analysis of dwellings' temperatures to enhance validation of the building simulation process.

2. Methodology

2.1 Background

The goal is verification, through an established method comparison study, of the agreement between monitored temperatures and thermal analysis operating temperatures of a detached dwelling. The detached dwelling used as the case study is 49 Carnation Drive; this is a 1995 three-bedroom house located in Bracknell, Berkshire, about 48 km from Central London, the closest weather station. Hence the current Cibse London test reference year (TRY) is chosen for the analysis.

2.2 Thermal analysis simulation (TAS) 3D modelling and simulation

Thermal analysis simulation software TAS version 9.3.1, a building simulation program developed by Engineering Development Solutions Software (EDSL, 2014), is used as a dynamic simulation modeller to model and simulate the thermal performance. This current version has been approved and has the full accreditation for the UK Building Regulations 2013 and it has also demonstrated compliance with various BS EN ISO standards (EDSL, 2014). TAS has the capability to overcome the challenge of applying the 'vast quantity of data to assess the probabilistic performance of buildings in the future' (Williams *et al.*, 2011). Moreover, it offers complete solution as a powerful modelling and simulation tool in the optimisation of building environment, energy performance and occupant comfort.

Building performance simulation requires the appropriate selection of modelling parameters and assumptions. The following assumptions were made in this work

(*a*) acceptability of Cibse TRY weather data set, which is based on an historic data pattern to be applicable to actual weather conditions of the case study building location
(*b*) acceptability of the standardised national calculation methodology dwelling internal conditions activity and occupant behaviour as the prevailing conditions of the case study building
(*c*) assuming U-values to be static instead of dynamic as they vary with thermal and climatic conditions.

The data used were the AutoCAD two-storey residential detached buildings architectural drawings of 49 Carnation Drive. The building drawings consisted of the ground floor and first floor plans, see Figures 1 and 2.

Measurements of floors', doors' and windows' dimensions were taken from both the AutoCAD drawings and physical measurements of the case study building. The floor level was measured from the ground plane at datum 0·0 m. The default wall height dimensions were measured from the floor finish to directly below the floor finishing of the upper floor. The respective zones on the ground-floor and first-floor plans were noted and further grouped into bedrooms, circulation, toilet and miscellaneous.

To aid in the shadow calculations in the 3D modeller, the orientation of the north angle was changed to 135° clockwise to

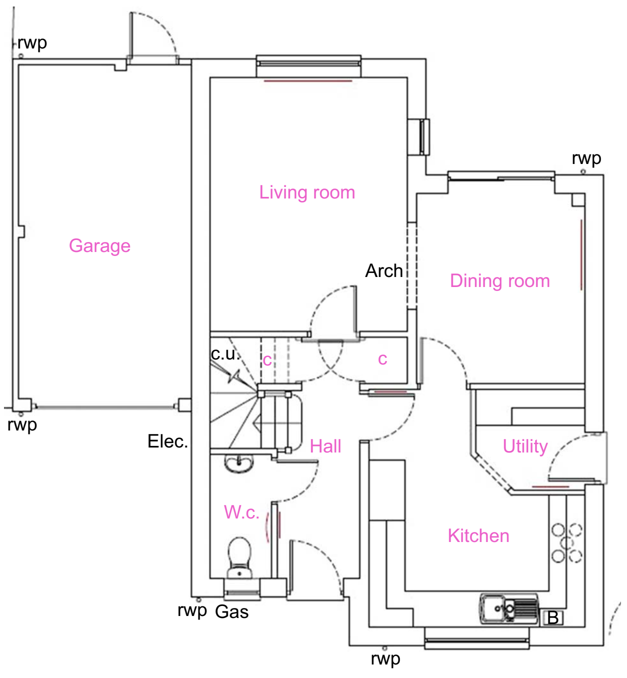

Figure 1. Ground floor plan (scale 1:50)

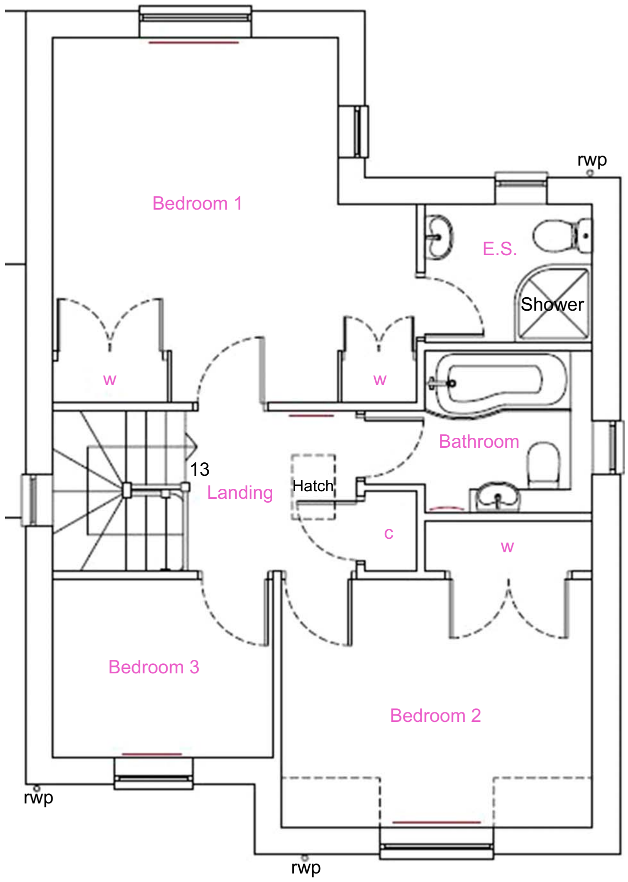

Figure 2. First floor plan (scale 1:50)

the north, and the latitude, longitude and time zone were changed to 51·42° north, −0·75° east and UTC (coordinated universal time) +0·0, respectively, to reflect the geographical and time parameters of Bracknell, Berkshire, which is about 48 km from Central London, the closest weather station.

The current Cibse TRY weather data set is based on historical data for London and thus does not perfectly reflect the microclimate of Bracknell, Berkshire. The accuracy is therefore first verified through the monitoring of the outdoor temperatures and the external temperature data from the thermal analysis simulation.

The flow charts in Figures 3, 4 and 5 illustrate the drawing files preparation for the 3D modelling process and the modelling of the ground floor, first floor and the roof arrangement, respectively.

The software TAS as a dynamic simulation modeller models the thermal mass of a building. The other simulation parameters of building summary, calendar, weather, zones, internal conditions, schedule and aperture types were populated to simulate the building so that it would reflect the construction design criteria specified by the Cibse Guide A (Cibse, 2006) and TAS for dwellings. Figure 6 is a flow chart showing the thermal simulation process, with its associated modelling and simulation parameters in Tables 1 and 2.

The UK Building Regulations studio used by the TAS EDSL 9.3.1 software is based on 2013 regulations. It adheres to the national calculation for methodology (NCM) for the energy performance of buildings directive (DCLG). The UK Building Regulations studio is systematically worked through by

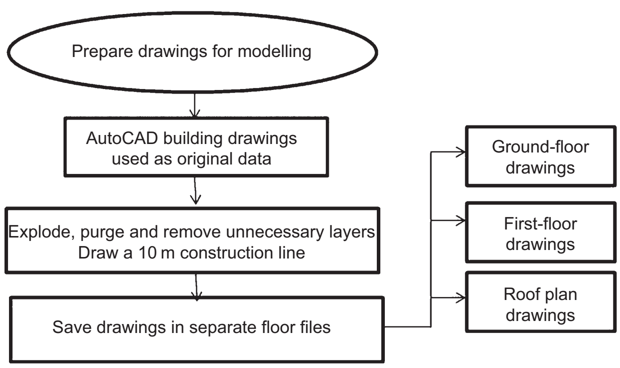

Figure 3. Preparation of drawings for modelling

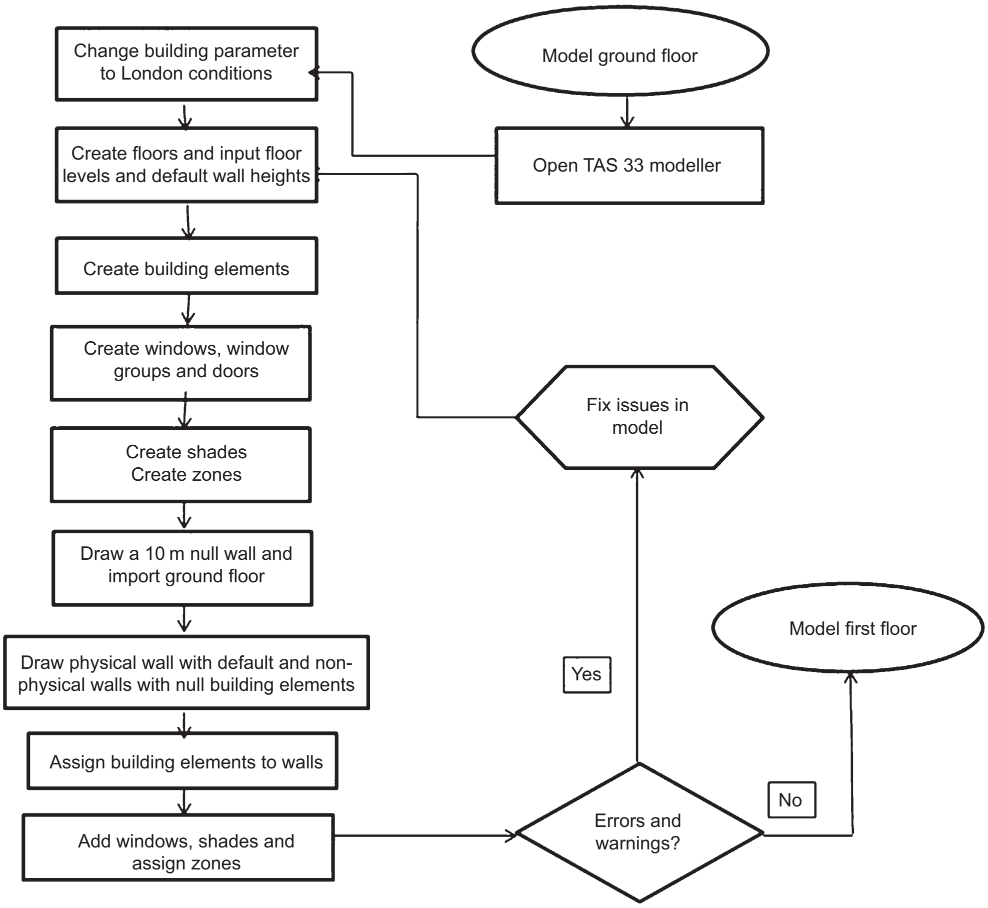

Figure 4. Ground floor modelling process

appropriately selecting various parameters and circuit configuration leading to the generation of a series of building reports from which data based on simulated temperature results and thermal performance data for the study are extracted for analysis. The kitchen operating temperature was calculated as the average of the dry bulb and mean radiant temperatures. Figure 7 illustrates the flow chart of the simulation processes in the UK Building Regulations studio.

2.3 Temperature monitoring

The monitored outdoor and kitchen temperatures were conducted using temperature sensors calibrated to a high degree of accuracy and using a light-emitting diode reader to facilitate accurate reading. The temperature data were recorded every 15 min and the data were stored online. The 15 min recorded temperatures were collapsed into hourly averages to synchronise with TAS hourly dynamic simulated temperatures, which are based on the Cibse TRY weather information.

The outdoor temperature monitoring was undertaken between March and May 2014, to analyse the current temperature variability with the temperature data of the Cibse weather file. The kitchen operating temperatures were monitored between February and May 2014, for comparison with the thermal analysis simulated operating temperature results.

2.4 Bland–Altman method

Bland–Altman or limit of agreement plot (Bland and Altman, 2007) is a method comparison graphical analysis which seeks to validate the interchangeability of two techniques. This statistical evaluation indicates the agreement between the two methods. The Bland–Altman limits of agreement method stipulates that neither the Pearson's correlation coefficient nor regression techniques are adequate for comparison of two methods (Bland and Altman, 2007). Bland–Altman's procedure is acceptable for temperature comparison of two methods as it 'assumes a linear relationship between errors and measurements' (Hanneman, 2008). The basic steps in the

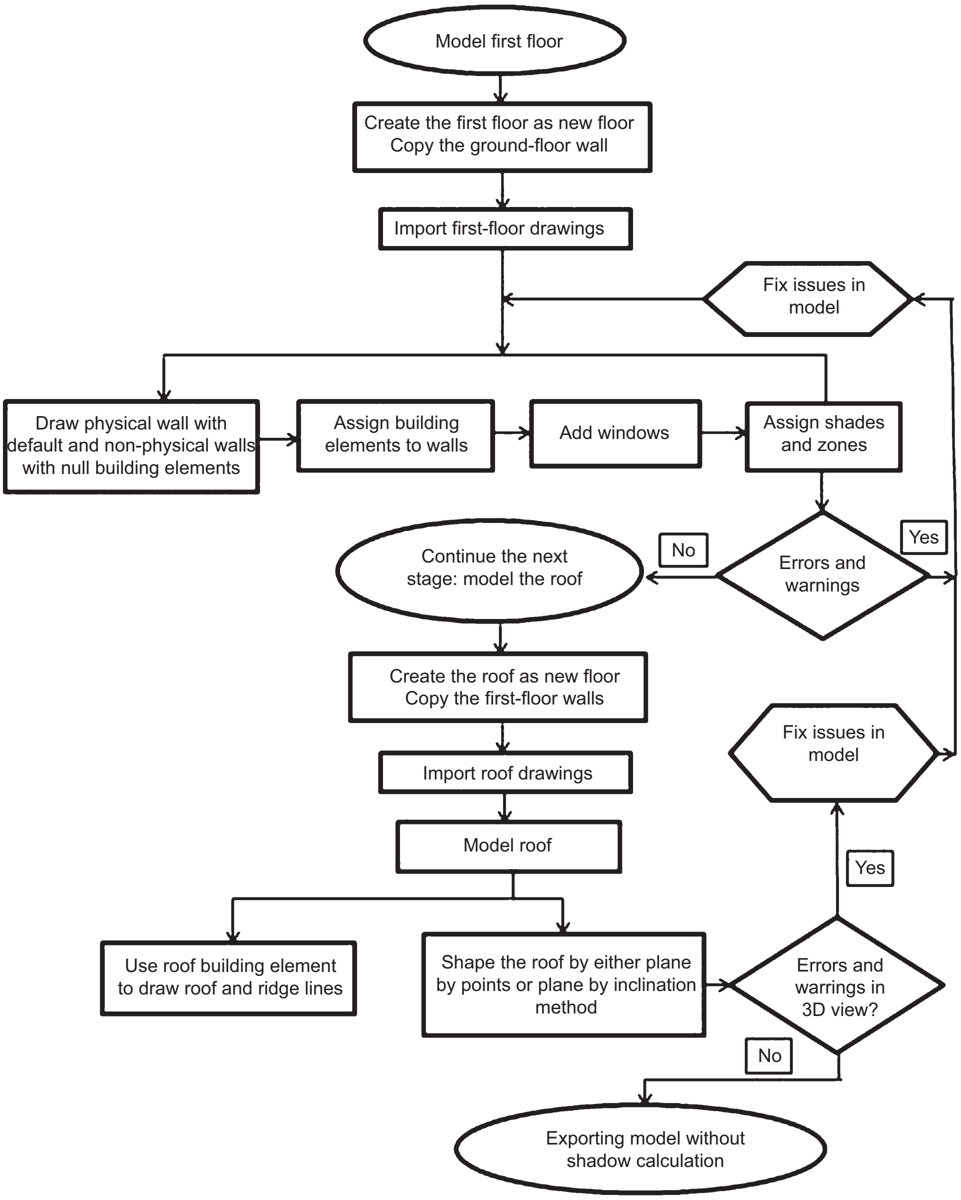

Figure 5. First floor/roof modelling process

Bland–Altman analysis used in this work included the following

(*a*) Establish the pre-established criteria for the bias and precision
(*b*) Examine the data and eliminate outliers
(*c*) Plot scatter diagrams with line of equality of monitored and simulated temperatures
(*d*) Determine the normality of the temperature differences of sets of monitored and simulated temperature distribution using histogram and normal probability plot (normal Q–Q plot)
(*e*) Plot the differences of temperature of each pair of monitored and simulated temperatures on the vertical axis against the means on the horizontal axis
(*f*) Determine and plot the mean difference and the limits of agreement based on 95% confidence limits of normal distribution, that is $\pm 1{\cdot}96$ standard deviation of the mean difference
(*g*) Determine the limit of agreement recommended conditional agreement between the two methods when 95% of the plotted data lie between the limits of agreement

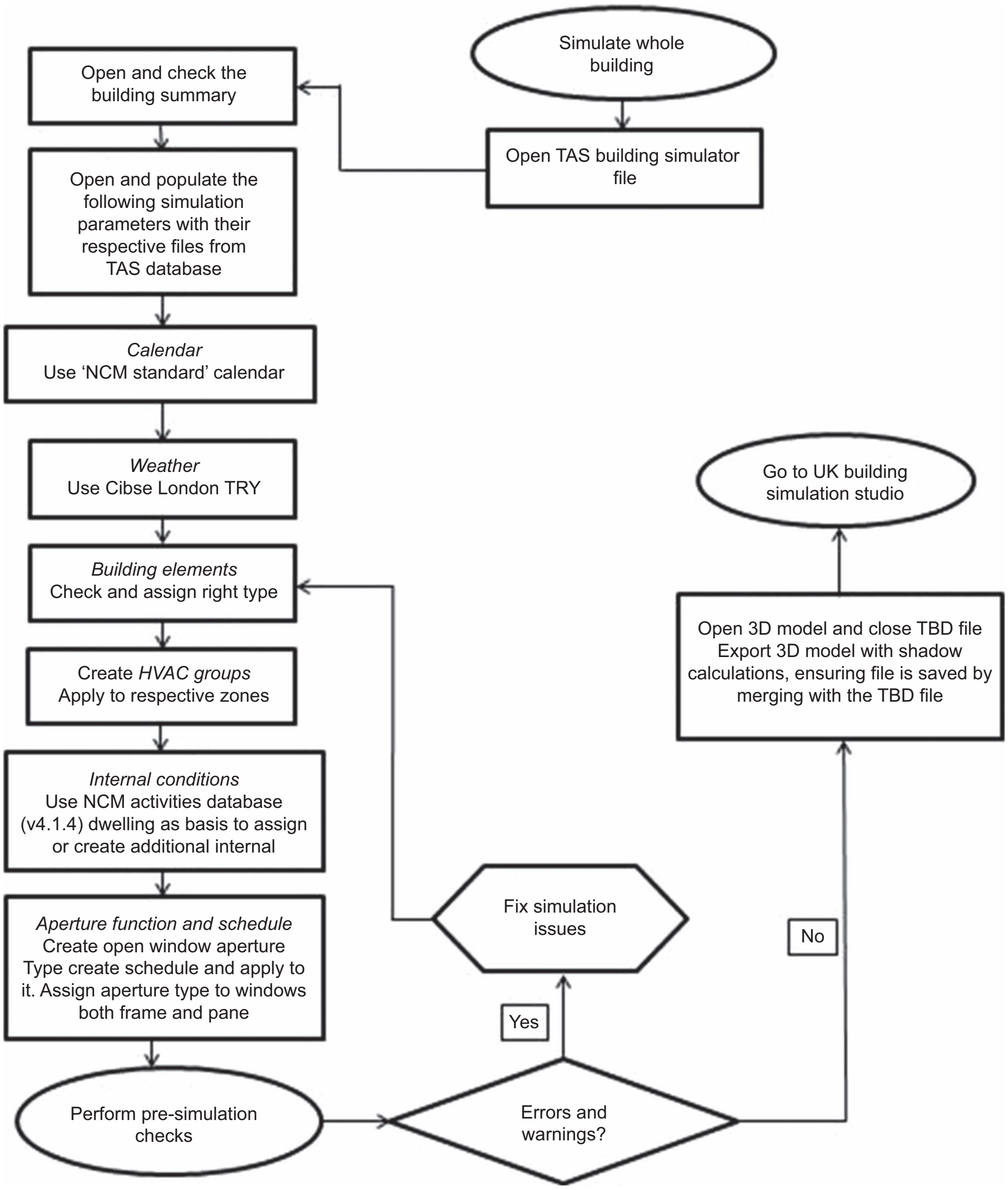

Figure 6. Thermal simulation process (HVAC: heating, ventilation and air conditioning)

(*h*) Determine the percentage error
(*i*) Report and discussion should be based on findings against the set pre-established criteria, the mean value of the two techniques, the standard deviation of the difference and the limits of agreement.

In their Ashrae RP-884 and the new adaptive comfort standard for Ashrae standard 55 studies, de Dear *et al.* (1997) defined the width of comfort range of temperatures for naturally ventilated buildings with 90% and 80% acceptability to be 5 and 7°C, respectively, with their corresponding mean thermal sensation of $\pm 0{\cdot}5$ and $+0{\cdot}85$, respectively (Brager and de Dear, 2001; de Dear *et al*., 1997). These are acceptable international standards. Peeters *et al.* (2009) indicated the asymmetrical split of the thermal comfort width band. Hanneman (2008) indicated that a higher pre-established criterion for bias could be set 'to account for the inherent measurement error' if the bias of the findings and the agreement between the methods would be

Building fabric		
Calculated area weighted average U-values	Wall	0·42 W/m^2 K
	Floor	0·46 W/m^2 K
	Roof	0·19 W/m^2 K
	Windows	3·29 W/m^2 K
	Door	2·74 W/m^2 K
	Garage door	1·77 W/m^2 K
Calendar	NCM standard	
Air permeability	10 m^3/hm^2 at 50 Pa	
Infiltration	0·500 ACH	
Lighting efficiency	5·2 W/m^2 per 100 lux	
Average conductance	172 W/K	
Alpha value	22·38%	

Table 1. Modelling and simulation parameters and assumptions

avoided. Thus a higher bias pre-established criterion of ±0·85 with a precision pre-established criterion band width of 7℃ could be set to correspond to the 80% acceptability of thermal comfort range.

3. Results and discussion

3.1 Bland–Altman method

The analysis of 49 Carnation Drive two-storey residential detached building is presented below. Figures 8(a) and 8(b) represent the outcome of the modelling process.

Figures 9–16 show the results of the Bland–Altman method for the analysis of the outdoor and kitchen operating temperatures. Hanneman (2008) emphasised the importance of data inspection to remove outliers as an important step preceding the Bland and Altman plot. Analyses of both scatter plots with their line of equality, Figures 9 and 10, show the visual impression of the agreement between the two methods. The line of equality is a line on which all the points should lie if the two methods gave the exact temperature values and thus formed a perfect agreement (Bland and Altman, 1986). The Pearson correlation coefficients (r) of 0·86 and 0·75 for the outdoor and kitchen temperature analyses point to a strong positive linear relationship (Pallant, 2013). Moreover, the p values of the two analyses are less than 0·0001, which point to a significant statistical relationship between the simulated and monitored temperatures with a very small probability of the association between the simulated and monitored temperatures being attributable to chance. It is obvious from the scatter plots that not all of the set paired data points lie on the line of equality. Thus, further analysis is required in the form of the Bland–Altman method.

The Bland–Altman plot is underpinned by a parametric statistical test of normal distribution of the differences of the sets of paired simulated and monitored temperatures. This is because the 95% limits of agreement depend on the statistical

Construction database		NCM construction – v5.2.tcd
Occupancy levels; People density; Lux level	Bath	0·01873684 person/m^2, 150 lux
	Bed	0·01873684 person/m^2, 100 lux
	Circulation areas	0·02293877 person/m^2, 100 lux
	Dining	0·0169163 person/m^2, 150 lux
	Kitchen	0·0237037 person/m^2, 300 lux
	Lounge	0·0187563 person/m^2, 150 lux
	Toilet	0·02431718 person/m^2, 100 lux
Fuel source	Natural gas	Carbon dioxide factor – 0·216 kg/kW h
	Grid electricity	Carbon dioxide factor – 0·519 kg/kW h

Table 2. Modelling and simulation parameters and assumptions

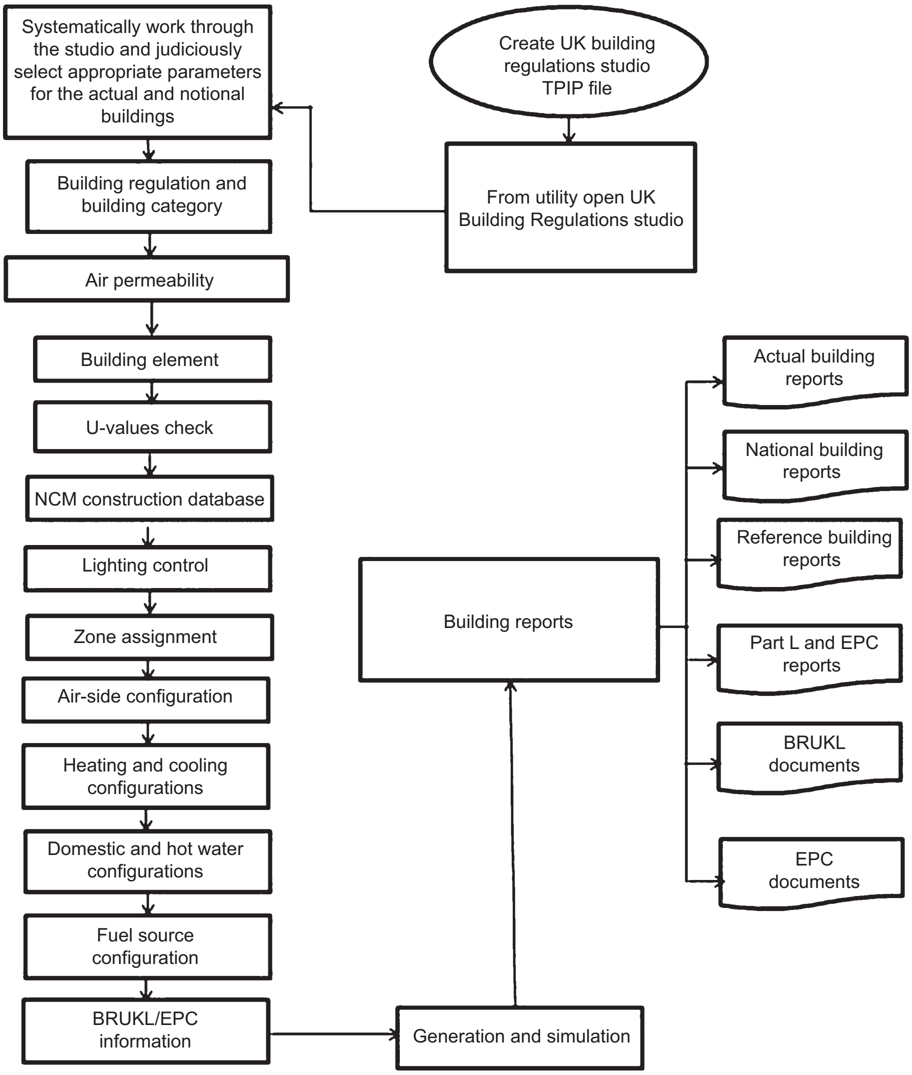

Figure 7. UK Building Regulations studio simulation. TPLP, Building Regulations studio project file; EPC, energy performance certificate; BRUKL, Building Regulation UK Part L

Figure 8. Modelling results

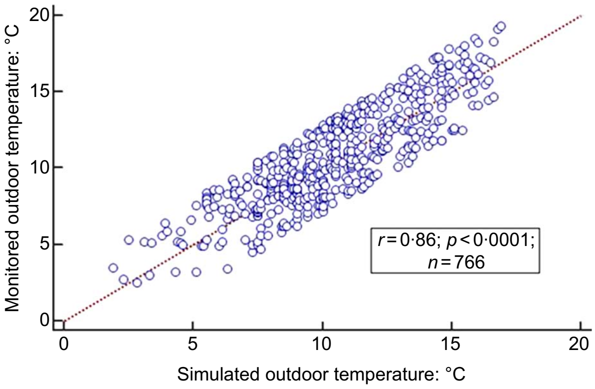

Figure 9. Outdoor temperatures scatter plot with line of equality

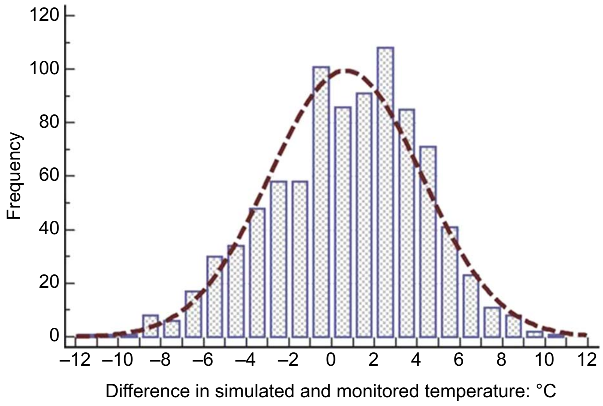

Figure 11. Frequency distribution of outdoor simulated and monitored temperatures

assumption that the differences of the paired set of temperatures will give constant mean and standard deviation (Bland and Altman, 2003). Thus, Figures 11 and 12 show histograms of the differences of the temperatures, which provide evidence of reasonably normal distribution. The normal distribution assertion is reinforced by the inspection of the normal Q–Q plots, Figures 13 and 14, which show the observed values plotted against the expected values to be a reasonably straight line, further pointing to normal distribution (Pallant, 2013). The Kolmogorov–Smirnov statistic was not used in the analyses as its significant value tends to be quite small when dealing with large sample size, making it inappropriate to be used in this instance to assess the distribution normality (Pallant, 2013).

Figure 15 gives the Bland–Altman plot for the differences between the outdoor simulated and monitored temperatures against their means. Some 86% of the total 890 sets of paired temperatures data collected in the period ranging from March to May 2014 were used for the analysis after the removal of outliers. The mean difference of temperatures was 0·3℃ with the standard deviation 1·7℃, giving the 95% limits of agreements of −3·0℃ to 3·6℃. The bias and the precision are within the pre-established criteria set at the beginning. The standard errors of the limits are expressed as $((3 \times \text{standard deviation}^2)/n)^{1/2}$, where n is the number of sets of paired temperatures. The standard error is thus given as 0·11. The analysis showed that a substantial amount of the plotted data (greater than 95%) lay between the limits of agreement, indicating a very strong agreement between the outdoor monitoring temperatures and the TAS simulated external temperature based on the Cibse weather data file. Thus, with

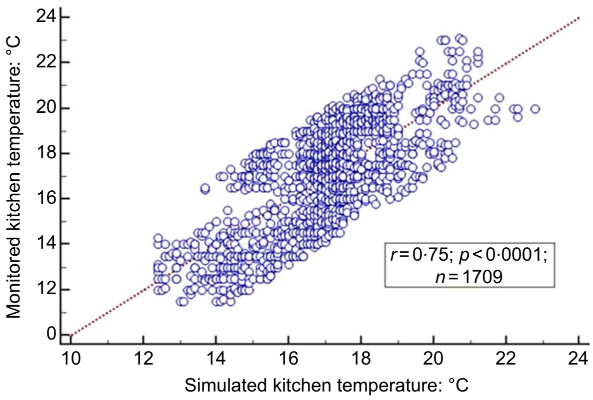

Figure 10. Kitchen operating temperatures scatter plot with line of equality

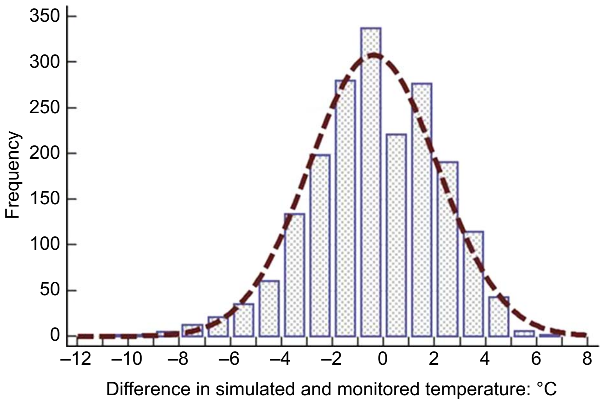

Figure 12. Frequency distribution of kitchen simulated and monitored temperatures

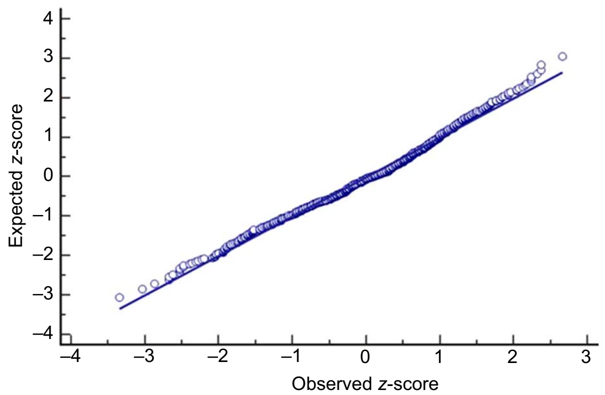

Figure 13. Normal Q–Q plot of the difference between outdoor simulated and monitored temperatures

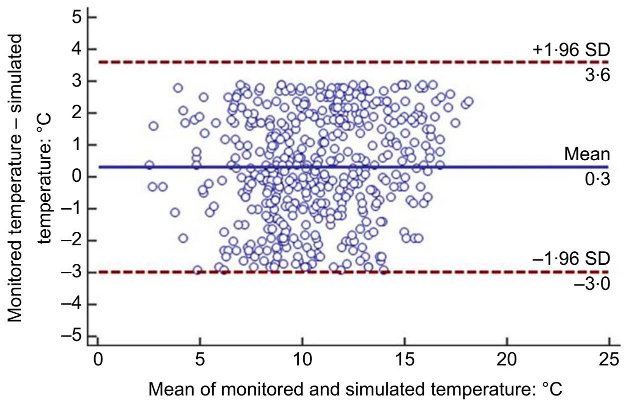

Figure 15. Bland–Altman plot outdoor temperatures (SD: standard deviation)

the external temperature as the only uncertainty in the simulation analysis, a very strong agreement is realised between the monitored outdoor temperatures and the thermal analysis simulated temperatures, which therefore validates the TAS program based on the weather data alone.

Further Bland–Altman analysis, which takes into consideration the simulation of kitchen operating temperatures coupled with the monitoring temperatures, is shown in Figure 16. Some 88% of the total 1942 sets of paired temperatures data collected in the period ranging from February to May 2014 were used for the analysis. The mean difference of the kitchen operating temperatures was 0·1℃ and the standard deviation was 1·6℃. The 95% limits of agreements were −3·0℃ to 3·2℃. The bias and the precision are again within the pre-established criteria set at the beginning. The standard error is calculated to be 0·07. The analysis of the kitchen operating temperatures indicated that a substantial proportion of the plotted data (greater than 95%) lay between the limits of agreement, showing a very strong agreement between the kitchen monitoring temperatures and the TAS simulated kitchen operating temperatures, and thus the analysis using the Bland–Altman method validates the TAS program as credible and acceptable software for building thermal analysis simulation.

4. Conclusion

The work has presented the use of the Bland–Altman comparison method as a thermal analysis simulation program validation technique and has affirmed that the accuracy of building thermal performance can be predicted using the TAS program. The analysis entailed statistical evaluation of the agreement between monitored temperatures and predicted

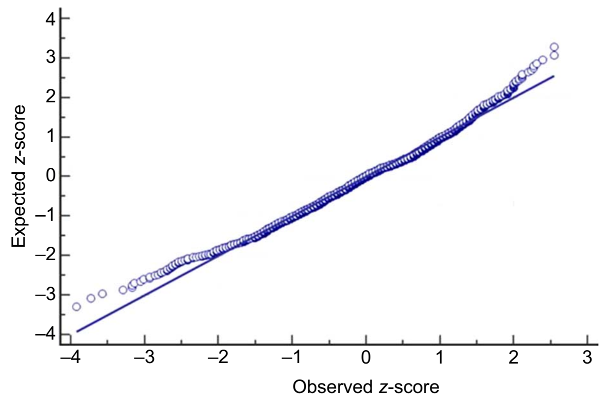

Figure 14. Normal Q–Q plot of the difference between kitchen simulated and monitored temperatures

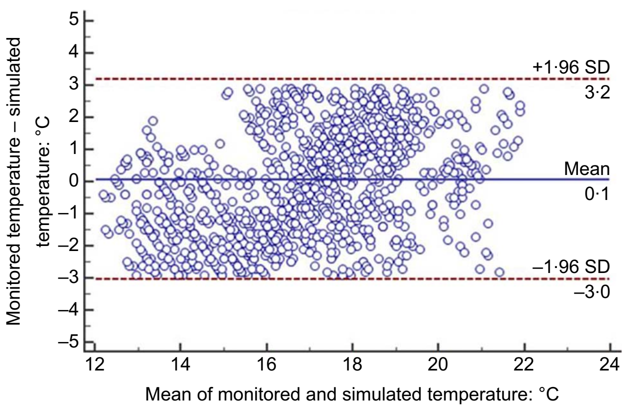

Figure 16. Bland–Altman plot kitchen temperatures

thermal analysis simulated operating temperatures of detached dwellings in the UK. The analysis showed a very strong agreement between the outdoor monitoring temperatures and the TAS simulated external temperature based on the Cibse weather data file. Thus, with the external temperature as the only uncertainty in the simulation analysis, a very strong agreement was realised between the monitored outdoor temperatures and the thermal analysis simulated temperatures, thereby validating the TAS program based on the weather data alone. The analysis of the kitchen operating temperatures also indicated that a substantial proportion of the plotted data lay between the limits of agreement, which showed a very strong agreement between the kitchen monitoring temperatures and the TAS simulated kitchen operating temperatures, and thus the analysis using the Bland–Altman method validated the TAS program as a credible and acceptable software for building thermal analysis simulation.

The conclusions are drawn from the British Standards Institution's definition of a repeatability coefficient, which stipulates that 95% of the differences should be less than two standard deviations (BSI, 1975). Professionals in the built environment may be required to make a judicious decision as to the degree of level of agreement that would be acceptable in simulation practice. The procedure outlined is acceptable for temperature comparison of two methods as it assumes a linear relationship between errors and measurements. For non-linear and perhaps more complicated uncertain parameters, additional numerical issues may have to be addressed.

REFERENCES

Amoako-Attah J and B-Jahromi A (2013) Impact of future climate change on UK building performance. *Advances in Environmental Research (AER): An International Journal of Interdisciplinary Research in Environmental Science, Technology, and Management* **2(3)**: 203–227.

ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) (2002) *ASHRAE Guidelines 14-2002 for Measurement of Energy and Demand Savings*. ASHRAE, Atlanta, GA, USA.

Bland JM and Altman DG (1986) Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* **1(8467)**: 307–310.

Bland JM and Altman DG (2003) Applying the right statistics: analyses of measurement studies. *Ultrasound Obstetric Gynaecology* **22(1)**: 85–93.

Bland JM and Altman DG (2007) Agreement between methods of measurement with multiple observations per individual. *Journal of Biopharmaceutical Statistics* **17(4)**: 571–582.

Brager GS and de Dear R (2001) Climate, comfort and natural ventilation: a new adaptive comfort standard for ASHRAE Standard 55. In *Proceedings of Moving Thermal Comfort Standard into the 21st Century*. Oxford Brookes University, Windsor, UK, pp. 60–77.

Brazdzionyte J and Macas A (2007) Bland–Altman analysis as an alternative approach for statistical evaluation of agreement between two methods for measuring hemodynamics during acute myocardial infarction. *Medicina (Kaunas)* **43(3)**: 208–214.

BSI (1975) BS 597: Precision of test methods. Part 1: Guide for the determination and reproducibility for a standard method. BSI, London, UK.

Cibse (Chartered Institution of Building Services Engineers) (2006) *Cibse Guide A – Environmental Design*. Chartered Institution of Building Services Engineers, London, UK.

Cibse (2013) CIBSE TM54:2013: Evaluating operational energy performance of buildings at the design stage. Chartered Institution of Building Services Engineers, London, UK.

Climate Change Act 2008 (2008) *Elizabeth II. Chapter 27*. Her Majesty's Stationery Office, London, UK. See http://www.legislation.gov.uk/ukpga/2008/27/contents (accessed 25/04/2014).

de Dear RJ, Brager GS and Cooper DJ (1997) *Developing an Adaptive Model of Thermal Comfort and Preference – Final Report*. MRL, Sydney, Australia, Ashrae RP-884.

EDSL (2014) *TAS*. Environmental Design Solutions Ltd, Milton Keynes, UK. See http://www.edsl.net/main/Software/Designer/NVandPD.aspx (accessed 10/05/2014).

Georgiou G, Efttekhari M and Eames P (2014) Calibration and validation of residential buildings: 8 case studies of detached houses. In *Proceedings of Building Simulation and Optimization, 2nd IBPSA–England Conference on Building Simulation and Optimization, UCL, London, UK*. IBPSA, London, UK.

Hanneman SK (2008) Design, analysis and interpretation of method-comparison studies. *AACN Advanced Critical Care* **19(2)**: 223–234.

Hogg N and Botten C (2012) *A Tale of Two Buildings. Are EPCs a True Indicator of Energy Efficiency?* Jones Lang LaSalle and Better Building Partnership, London, UK.

Judkoff R, Wortman D, O'Doherty B and Burch J (2008) *A Methodology for Validating Building Energy Analysis Simulations*. National Renewable Energy Laboratory, Golden, CO, USA, Technical Report NREL/TP-550-42059.

Lu K, Quach B, Tong TK and Lau PWC (2003) Validation of leg-to-leg bio-impedance analysis for assessing body composition in obese Chinese children. *Journal of Exercise Science and Fitness* **1(2)**: 97–103.

Pallant J (2013) *A Step by Step Guide to Data Analysis Using IBM SPSS,* 5th edn. McGraw-Hill, Maidenhead, UK, pp. 61–66.

Peeters LFR, de Dear R, Hensen JLM and D'Haeseleer W (2009) Thermal comfort in residential buildings: comfort values and scales for building energy simulation. *Applied Energy* **86(5)**: 772–780.

van Stralen KJ, Dekker FW, Zoccali C and Jager KJ (2012) Measuring agreement, more complicated than it seems. *Nephron Clinical Practice* **120(3)**: c162–c167.

Williams D, Elghali L, France C and Wheeler RC (2011) Projecting building energy demand using probabilistic weather conditions accounting for climate change. *Proceedings of Cibse Technical Symposium, DeMontfort University, Leicester, UK.*

Witte MJ, Henninger RH, Glazer J and Crawley DB (2001) Testing and validation of a new building energy simulation program. *Proceedings of the 7th International IBPSA Conference, Rio de Janeiro, Brazil*, pp. 353–360.