Why tools for buildings and cities performance simulation need to evolve

Joe Clarke *(Energy Systems Research Unit, University of Strathclyde)* describes the '7 deadly sins' associated with performance simulation tools. To overcome these, he argues that structural changes are needed involving the roles of construction industry, professional bodies, researchers and software developers.

Buildings are complex systems because their energy use and indoor environmental conditions vary dynamically under the stochastic influence of weather, occupants and component erraticisms. Addressing this complexity has been the principal driver of the evolution of performance simulation tools since the beginning of the personal computer era in the 1970s. Despite the significant progress that has been made since then – as evidenced, for example, by the array of tools posted at the Building Energy Software Tools directory – it is evident that a gap is growing between tool capability and the widening and deepening aspects of the clean energy transition as it affects buildings and cities. This unwelcome situation stems from the growing pressure to radically reduce city energy demand, integrate cleaner sources of energy supply, ensure that indoor/ outdoor spaces promote human wellbeing, and mitigate local / global environmental impacts; all while addressing interacting technical domains, diverse performance expectations and pervasive uncertainties. It is here contended that the ultimate goal of built environment performance simulation, when applied at whatever scale, is to provide practitioners with the means to emulate reality in a manner that renders operational resilience more likely. Such a capability portends a future in which the conjugate heat, air, moisture, light, sound, electricity, pollutant and control signal flows are simulated in an integrated manner on the basis of high resolution descriptions of proposed schemes subjected to industry standard performance assessment procedures. The merits of an approach that enables whole system, multi-variate performance appraisal under realistic operational scenarios cannot be understated. The challenge is to ensure that future performance simulation tools evolve in a reasonable time frame to provide the required functionality.

Creating such highly functional software tools, and embedding these within the design process, is a non-trivial task that is hindered by the present situation where the development community encompasses diverse technical and business interests and has yet to evolve mechanisms by which long term development goals can be agreed and collectively pursued. This situation gives rise to, and is exacerbated by, the '7 Seven Deadly Sins' of software tool development as previously identified by Maver (1995) in the context of Computer-Aided [illegible] ation.

1. Macro-myopia

This relates to the often heard claim that a tool is all-singing, all-dancing and easy to use. However, there is no acknowledgement of a tool's deficiencies, how these relate to the long term aspirations of the community, and how software is actually used. This situation derives from commercial and academic pressures on tool creators that make it difficult for them to admit that their product is other than uniquely state-of-the-art, to acknowledge that other tools may in some respects be more advanced at any point in time, and to engage more with the contributions from the wider community. Addressing this issue would, at the very least, act as a catalyst for developer collaboration and better tool interoperability.

2. Déjà vu / amnesia

This is the re-emergence of ideas that have striking similarity to earlier work but with no attempt to openly acknowledge or build upon what went before. Inappropriately mentored newcomers to the field often proffer solutions that have been previously tried and rejected or, more problematic, expend considerable effort implementing methods that do not contribute any new assessment functionality. This situation is often compounded by 'hiding' such solutions behind user-friendly but misleading user interfaces.

3. Xenophilia

This is the importing of concepts from other disciplines (most typically computer science) that divert intellectual effort from researching what lies at the heart of the buildings and cities performance simulation challenge. A common example is a tool with an elegant optimisation algorithm that acts on results from a simplified core that gives misleading outputs by design. The absence of city performance simulation as a core discipline makes it difficult to justify R&D funding resulting in slow progress and low impact.

4. Non-sustainability

This is where the R&D effort is devoted to over-indulgent tool development, such as the reimplementation of existing methods corresponding to a new software engineering paradigm (such as object-oriented programming), with little attention given to researching design solutions that yield improved quality of performance to building clients and users. This results in 'new' tools of diminished capability when compared to what went before. Indeed, tool vendors, commercial or academic, are more likely to announce a 'stunning new feature' – BIM model import, legislation compliance support, user plug-in capability *etc*. – than invest effort in understanding how their tool can improve design solutions.

5. Failure to validate

This is where a plethora of exotic claims relating to predictive preciseness are not subjected to any independent verification. In most other disciplines this situation is considered unacceptable. The existence of an independent tool accreditation agency or, at the very least, the requirement that tools encapsulate standard validation tests that can be activated by users, would do much to eliminate spurious claims and improve tool fidelity vis-à-vis the real world.

6. Failure to evaluate

This is where there is no independent investigation of tool ease of use and applicability to real problems. The absence of credible user feedback means that future R&D is undirected and vulnerable to academic drift. The professional bodies could usefully take the lead in activities focused on applications requirements capture in order to identify necessary new functionality, bring forward application standards, and inform the content of training provisions for practitioners.

7. Failure to criticise

This is where a community conspires to condone or even encourage self-indulgent speculation and solipsism: a bad example to set for the next generation of researchers and developers. A useful role for construction sector bodies would be to initiate activities that bring constructive criticism to bear on the capabilities and application deficiencies of all tools as a means to influence the funding bodies and thereby ensure a better future.

In summary, tool developers are forced to address disparate requirements relating to user interfaces, data model manipulation, mathematical models, numerical methods, database management, software engineering, outcome validation, user documentation and the like. Because there is limited development sharing, and since no single organisation will possess the necessary expertise in all areas, contemporary tools have substantial deficiencies relative to the reality. To compound the problem, tools are promoted by vendors in a manner that hides deficiencies and implicitly or otherwise undermines the development effort expended by others. This is an unacceptable situation that serves only to fragment the development effort. The consequence of such behaviours is a slow pace of change, lack of standards, unnecessary duplication of effort, tension between developers, and a plethora of software tools all with substantial shortcomings.

One professional body – the International Building Performance Simulation Association (IBPSA) – has taken action to address the above issues through the publication of a futures vision for the discipline (Clarke, 2015) and through the fostering of activities to direct the called-for developments. What is now needed is for the construction industry itself to take a proactive role in directing tool evolution and application. Such a role could usefully address questions such as:

- *What are the costs and benefits of the high resolution simulation approach?*
- *How can a business identify the correct software tools for its needs?*
- *Who should provide independent tool validation and accreditation?*
- *How can modelling tools best be embedded within a business?*
- *What are the different roles required from members of a simulation team?*
- *What training will staff require and who can provide this?*
- *In what ways will business work practices need to be adapted?*
- *How are high resolution models constructed and quality-assured?*
- *Where will I find approved databases for use in model definition?*
- *How are models calibrated before use and documented and archived thereafter?*
- *What are the requirements for standard performance assessments?*
- *What performance criteria should be used to appraise overall performance?*
- *What are the business risks and rewards associated with investing in the technology?*

Some progress in these regards has already been made with professional bodies such as CIBSE and ASHRAE establishing mechanisms to support tool use in practice – such as the work of the Building Simulation & Energy Modelling group and Building Energy Modelling

Professional Certification programme respectively. In a recent project, a CIBSE-led initiative involving industry and academic partners set out to establish an approach to the automated assessment of the operational resilience of submitted proposals (Clarke and Cowie, 2020) based on long term simulation.

Only by guarding against the 7 Deadly Sins and finding answers to pertinent questions such as those listed above, will performance simulation tools become demonstrably quicker, cheaper and better than the traditional approaches to design options appraisal that they seek to replace. That is an exciting prospect for the construction industry: improved performance through an easy to access, low cost computational approach to buildings and cities performance quality assurance at the design/ retrofit stage.

References

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