Leveraging data in academia and practice: Geometry, human- and building-performance

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ABSTRACT: Data plays an increasingly critical role in every facet of the building lifecycle, from design and construction to building operations. Data is used in design and planning to not only generate designs and create interesting geometry, but to help designers acquire insights and answers out of the information they are already working with to validate their outcomes. The acquisition and leveraging of data will become a critical practice approach with implications for defining the future course of architectural research. Specifically, data helps increase energy and building performance and improves productivity, enhancing human and operational performance, as it predicts a facility's future performance; eliminates emotion from the decision-making process, allows teams to make decisions with more confidence by proving that initial concepts were right; and provides objective evaluations of all aspects of the built environment.

Based on qualitative research involving interviews and observation of the work of 40 practitioners (30 professionals and 10 academics) across the globe, and sharing their recommendations, insights and strategies, this approach to research addresses a gap in our professional learning, by researching how architects, engineers, contractors and owners – and educators in these fields – acquire and use data to make more informed decisions. Data informed design is a trend in architecture/ engineering/ construction/ operations (AECO) that is just starting to gain notice, and is the new frontier of the convergence between building information modeling (BIM) and architectural computational analyses, associated processes and technologies. There's a need for research that shows not only why design and construction professionals need to understand where data and analysis fits into their practices, but also how they can use data and analysis to meet and exceed their client's expectations.

Keywords: Data, Building Performance, Analysis, Analytics, Computational Design

INTRODUCTION

This paper focuses on the opportunities and challenges of capturing, analyzing and applying building data. It asks, and seeks to answer; important questions that design and construction professionals, owners and their teams, need to clarify in order to proceed with their design agendas. The research methodology looks inside practices of all sizes to observe how people in the architecture/ engineering/ construction/ operations (AECO) industry today are leveraging data in their day-to-day work. Accordingly, individuals and organizations in the profession and industry are already leveraging data, and for some firms have been doing so for some time to considerable effect and results. Based on research involving interviews and observations of the work of 40 professionals (30 practitioners and 10 academics) across the globe, and sharing their recommendations, insights and strategies, this approach addresses a gap in our professional learning, by researching how architects, engineers, contractors and owners – and educators in these fields – acquire and use data to make more informed decisions.

There is a need for research that explains not only why design and construction professionals need to understand where data and analysis fits into their practices, but also how they can go about using data and analysis to meet and exceed their clients' expectations. Based on the aforementioned interviews and on-site observations, the acquisition, leveraging and application of data is becoming a critical practice and research approach for many current practices, with implications for defining the future course of architectural research. Design and construction professionals need to increase productivity [Teicholz, 2013.] Based on this research, data helps increase energy and building performance and improves productivity, enhancing human and operational performance, as it predicts a facility's future performance. Data also eliminates emotion from the decision-making process, allows teams to make decisions with more confidence by proving that their initial concepts were right, and provides objective evaluations of all aspects of our built environment.

Data is changing the way we work in the AECO industry, and has the potential to change how we learn. Practitioners and educators have already dealt with successive disruptive technologies – computer aided design (CAD), building information modeling (BIM), digital-, parametric-, and computational-design tools, to name a few – and aren't certain if they're prepared for another. As though to say, aren't architecture, engineering and construction already complex and complicated enough? These are all ways of saying the same thing: that data is *one more thing*. As the research bears out, looking at, capturing, engaging with, analyzing, and applying data is not "one more thing." As this paper attempts to make clear, data is not

something *added* on to what design professionals, educators and researchers are currently doing, but rather something that is *integral* to what they do and have been doing, even if not historically always accomplished computationally.

In the interviews, design and AECO industry professionals indicate that they realize that data is the answer to their most perplexing professional and business problems – but suspect that many others are still unfamiliar with the steps necessary to acquire and use the data that will enable them to do their jobs better, remain competitive and achieve a higher return on their technology and training investment. Even more than the acquisition of new skillsets and technological capabilities, to reclaim their role as leaders, those interviewed believe that architects in particular need to simultaneously account for data and information derived from their digital models, and also be able to gather, navigate and communicate this information while working collaboratively through the project cycle. As the research indicates, all activities that we undertake today can be transformed into data – one only needs to know where to look to find it. The data, in other words, already exists – in abundance – and represents an opportunity that the profession cannot afford to ignore. This paper attempts to help state this more clearly and readily.

1.0 DESIGN COMPUTATION IN PRACTICE

One challenge in working with design computation in the AECO industry can be attributed to how firms perceive themselves in relation to data. Terminology needs to be defined before we can consider if there is as an ideal firm approach to data. Another challenge is the recognition that all forms of analysis ought to be considered when working with computational tools for integrating building-, human- and firm-performance. Learning to work more effectively with data will take not only newly acquired skills, such as the use of computational tools, but also the development of appropriate mindsets.

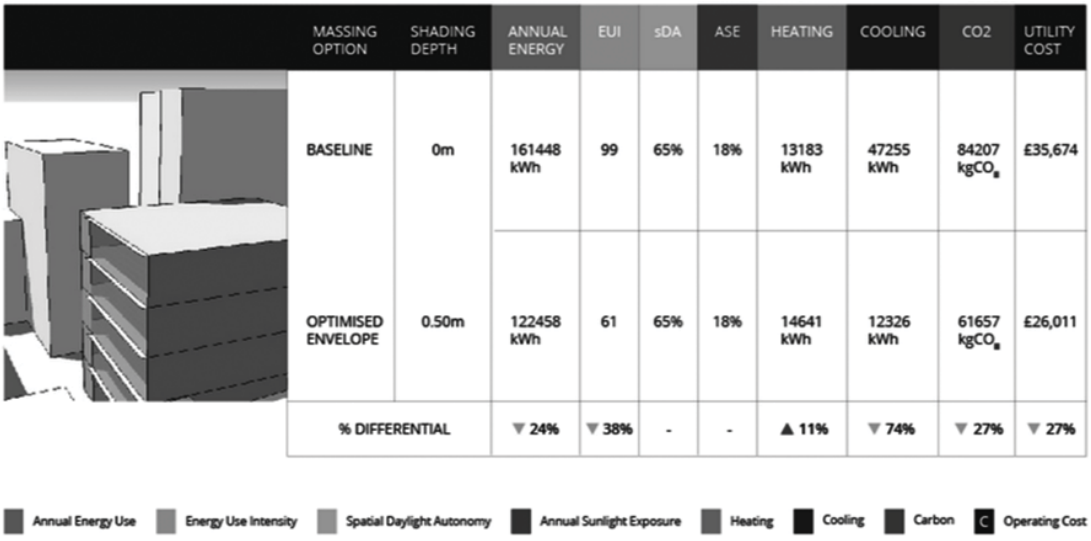

Figure 1: Baseline vs. Optimized Building Comparison: A representation of analysis results from Sefaira, showing the savings offered by an optimized envelope. (Sefaira Inc., 2014)

1.1. Tools and process

Firms are currently exploiting and innovating with computational design tools to make decisions in real- or near real-time. Design computation, software programs that use algorithms to link geometry with data to address specific problems, are utilized primarily to create geometry, for better building performance, or for both. According to Ryan Mullenix, Design Partner at NBBJ,

> It's all intertwined. The evolution of design computation has had moments of focus. Computation really started with building geometry. Part of it was as a cool tool with intriguing results. Part of it was, hey, this could lead to new means of fabrication; it could lead to efficiencies in the field. Then we got into building performance and the analyses we could perform to understand how a building was going to work within an environment. (Mullenix, 2014)

The goal ought to be where it is all put together – where geometry, human and building performance are inseparable – integrating building, human and firm performance.

Whether for geometry, human, or building performance – energy, sustainability, commissioning, lifecycle – it is important for design professionals to be able to test assumptions quickly in the early design phases.

Analysis will tell teams how well they are doing – how close to targeted goals they are. While the emphasis can overwhelmingly be on analysis for building geometry or energy, data can also be made available to the designer for analyzing the flow of people through space using software for simulating pedestrians and analyzing crowds. All forms of analysis ought to be considered when working with computational tools.

According to Robert Yori, Senior Digital Design Manager at SOM,

> In the broad sense, dealing with massive amounts of data is something architects have always done, although much of it hasn't historically been computational. The core question is this - how can we utilize the myriad types of data in a way to better our projects? (Yori, 2014)

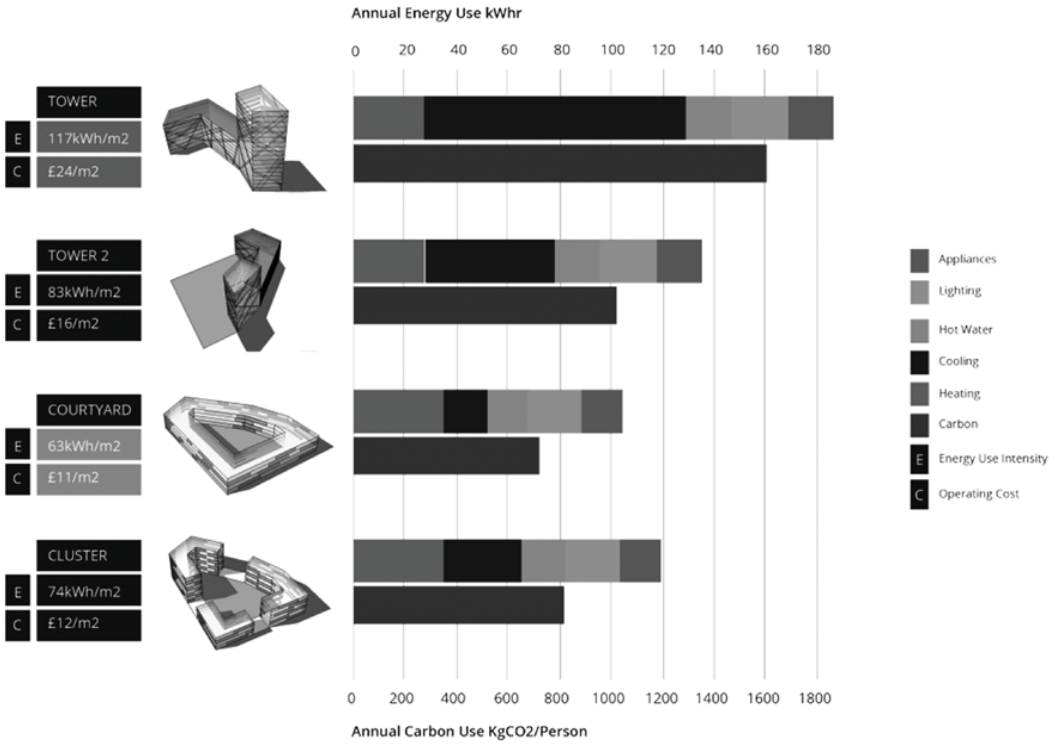

Figure 2: Building comparisons: Sefaira allows architects compare design options and measure their performance using chosen parameters. (Sefaira Inc., 2014)

1.2. Data informed: the middle ground

Before we can consider if there is as an ideal firm approach to data – whether one should strive to be a data-enabled, data-informed, data-driven practice – we need to define the terms. Data-driven: where data is the primary priority, involving up to 80% machine/algorithm input to 20% human intervention or override. At the other extreme, Data-enabled: where one is aware of the data but not leveraging it. A Data informed approach represents the middle ground: using data as a factor in the decision-making process.

Data informed design is a trend in AECO that is just starting to gain notice, and is the new frontier of the convergence between BIM and architectural computational analyses and its associated technologies. Does a firm like SOM – a firm that helped launch AEC-APPs and regularly queries their BIM models for pertinent data – consider itself data driven? "I can't characterize the whole firm one way, but certainly aspects of what we do at SOM are data-driven," says Yori, but adds, "and some are data-informed." As with the data-enabled approach, the choice is situational:

> There is some information that is better suited to being data-driven and some that is less so. So holistically, when we are approaching design, I would have to go with data-informed. Because there are some things that we do that are data-intensive. Some things that we do aren't so much. (Yori, 2014)

1.3. Capitalizing on data

How can we capitalize on data to drive innovation in architecture and construction? Learning to work more effectively with data will take some newly acquired skills. But even more important, especially at the beginning of this effort, is the development of appropriate mindsets. BIM is a case in point. While recognizing the value of BIM, most still use BIM tools today for document creation, at a time when design and construction professionals need to recognize BIM's real value: as a database, and start treating it like

one. How we use and interact with the data generated in BIM enabled projects is the next step in BIM adoption. Learning to capture, analyze and apply data is how many of us will take BIM, beyond visualization, clash detection and coordination, to the next level. One challenge to working with data in the AECO industry can be attributed to firms and how they perceive themselves in terms of data.

2.0 FIRM CULTURE, DEMOGRAPHICS, AND GENERATIONS

Will architects and other design and construction professionals need to adapt to working with, even alongside, data scientists and analytics experts? Some firms already have architects working alongside data scientists and analytics experts. Whether they do so comes down to firm size, their strategy, but as importantly, firm culture. Firm culture, the demographics and generations that make up the workforce, all make working with data challenging. "Data is different – it's new and it's scary," explains Evelyn Lee, Strategist at MKThink, acknowledging that data's challenges begin in school:

> With the current architecture curriculums, I don't think any of the students graduating right now have an issue with working with data. A lot of these programs have a cross-over with geographic information system (GIS) and energy modeling, which requires data. If you asked any of these graduates, they would tell you they would love to find a firm where I could put all of this into action. (Lee, 2014)

Yet, the same cannot be said for practitioners who are out of school:

> You ask a majority of firm leaders, though, in the architecture profession – and we all know that the architecture profession suffers from a generation gap – and they don't know what to make of it – data – and specifically how to apply it in a meaningful way. Individuals who have been around 10-20 years tend to be averse to it. In many instances, they are scared of finding out that the post-occupancy evaluation results tells them that their design was horribly designed. (Lee, 2014)

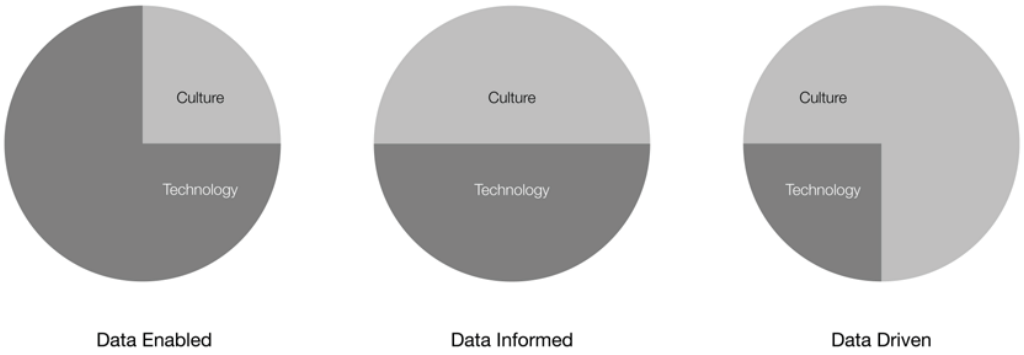

Figure 3: To become data-centric, the core of efforts ought to be focused on firm culture, not technology. (Deutsch, 2014)

3.0 LEVERAGING DATA IN EDUCATION

Should working with data be introduced into the college curriculum? Or will there be better results and increased impact if those in the profession and industry address data use in practice? There are many questions concerning when it is best to become exposed to integrating data analysis in the design process. But are there answers?

3.1. Addressing data from the start

Data is changing the way we work in the AECO industry – but is it having a similar impact on the way we learn? Just as data may be challenging to older generations, younger generations have the opposite problem. They may get so used to working with data they miss opportunities for developing or exercising critical thinking, or learning what the data is based on. Says Brian Ringley, educator at City Tech (CUNY) and Pratt Institute's GAUD:

> In the early stages of data-as-justification – we think of data-as-design-generator but also as justification of something to a client, public or team – there's justification of stuff we already know. We see this so often with students: the sun is always in the same spot this time of year. OK, we got that. (Ringley, 2014)

Ringley provides an example of how schools are exploiting and innovating with computational design tools to make decisions in real time:

> At one point, when teaching DIVA, I realized we needed to build a physical model, and that I needed to give them a crayon and have them color in where the insulation is occurring. Because it is as if once the data is there, common sense just falls to the wayside. We need to understand where the sun is relative to the building – go to the planetarium – before we get into this. A danger of introducing software at too early

> a stage in their education is that they were doing all the steps right – the workflow, the Grasshopper noodles were plugged in where they were supposed to go – but they had inverted the logic. So that the building was shading where there was no sun, windows were opening up where there was way too much sun. But they did all the steps right. That is a huge danger of data – I'm speaking here beyond the students and to the firm as a whole – there is trust in data that removes our critical thinking. We need to be careful about that and have ways to validate rules of thumb we already know. (Ringley, 2014)

Bringing attention to the topic of data ought to incentivize university programs to begin to address this topic in school, which does not happen often enough today. Students today are surprisingly unaware of issues related to leveraging data within architecture and construction management schools. This understanding and advanced use of data comes down to not only how, but when, one becomes prepared to do so.

3.2. Learning from data

Questions concerning learning to work with data are legion: How does one learn to work with data? When is it best to learn to work with data? Is it better to be exposed to it in school? Or wait until working in a practice? Who will teach architects to leverage data to further their designs? Who will assure contractors are up to speed on the multiple ways data informs on the jobsite? The experts I spoke with are all comfortable working with data. How did they get this way? Is it something they were born with? Or something they were exposed to when growing up? Was there something in particular in their education/training/background that prepared them for working in a data-led practice? What, if anything, in their education prepared them for a career working in data and taking an algorithmic approach to the work they do? When did they first realize that they were comfortable working in data? And realize the importance – or potential impact – of working with data? Was one parent an engineer who brought home a computer for you to take apart? What in their education prepared these design professionals for a career in the AECO industry where they are working in data alongside buildings and taking an algorithmic approach to the work that they do?

It is less about learning any one tool than having the confidence and wherewithal to pick up new tools for the task at hand. Where being proficient is no longer sufficient. "The tools are going to change every year," says David Fano, Managing Director of CASE Inc.

> They're not worried about having to learn a new interface. At my age – I'm in my mid-thirties – I don't want to get an Android because I don't want to learn a new interface. The younger kids aren't like that. They're not scared they're going to break it. My generation and up feels like they're going to break it. The younger generation fees like if they break it they'll get a new one or they'll fix it. I'm really excited about that. (Fano, 2014)

Should it be up to schools to implement data – to expose future design and construction professionals to working with data? Is school the right place for this to happen? Or would something be lost? Ringley again:

> When I was in school, Michael McInturf, working with Peter Eisenman for a while, then with his own office, was teaching this Maya course. It was insane how popular it was. People would sign-in after the course was capped. You'd have a computer lab full of students, then you'd have two rows of students holding laptops in the back. Because this knowledge was so precious, rare and exciting. Now, I get the sense that people will have this kind of CV checklist. I know 3D printing; I know CNC. I know Grasshopper. It's not about how amazing those softwares are. It's, I better fill my CV so I'm eligible for the jobs I want to have. (Ringley, 2014)

3.3. The human component

Our job as educators is not only to transfer information, but to inspire, spur curiosity, talk about possibilities. Working with data does not preclude the latter from happening, whether it is learning to work in robotics, energy modeling, or virtual and augmented reality. Working with data is as much a mindset as it is about the technology. Explains Fano:

> We've built technology that makes it easier. But it's really just a mindset. You'll go to some firms and see some guy tucked away in the corner who keeps a spreadsheet with metrics of every project they've ever done. It's really just a way of thinking. Excel is fine. A notepad would be fine. It's more thinking of information as this resource that you can go back and reference. Our mindset is very much like, next project, next project, and next project. (Fano, 2014)

What is it about education that leads to this behavior? Fano continues:

> School encourages that. How often in design studio do you see a critic tell a student after the first week, you nailed it. Done. That's counter to the whole idea. I've got to tell this kid to do something different. It's engrained in our thinking. Always do better, always challenge what you've done. Our thinking has to shift to what we've done is a resource to do better. How many studios in architecture school build on a previous studio? Almost none. You start from scratch. It's really just a shift in thinking. The tools or technology are whatever. Some will help you do it better than others. (Fano, 2014)

CONCLUSION

Design professionals need to increase their competency at leveraging data to remain competitive, to satisfy their client's need for evidence, and help make their claims credible. They need to learn how to work with data to verify their intuition and instinctive hunches, and to remain relevant in a business-oriented, STEM-centric world. Educators need to teach buildings as databases, not just as buildings or documents, and discontinue one-off projects: instead, have studios build on previous studios. Additional research on

successfully integrating data-relevant content into the curricula will be needed to help bring this about.

The alternative to learning to work with data in school is to rely on doing so in practice. Here, the onus is either on the firm to assure proper training or hiring staff to address computational design tools from a performance perspective. Alternatively, it is up to the employee to self-train outside of office hours. Again, familiarity with digital tools and technologies serves as a segue to a career where one predominantly works with data. This is becoming increasingly easier for the design professional explains Sean D. Burke of NBBJ:

> When I graduated from college, the economy was pretty bad. There weren't a lot of jobs. Eventually, I got a call – someone had recalled I was good at AutoCAD. Soon after getting the job, I put on the hat of CAD manager, tinkering, and writing AutoLISP. Today, with Dynamo, and more modern programming languages like Python, it's making it a lot easier for people to start to adopt new ways of working off of their existing tools without having to recreate everything from scratch. (Burke, 2014)

We as a profession and industry need to start thinking of buildings, and our work as building professionals, in terms of data, and to tell better data stories to our clients and stakeholders. We need educators who recognize the value of data and share this knowledge with their students, the future of the profession and industry. To move forward, we need research focused on defining and identifying problems that can be addressed with data, and a way of thinking about those problems to render them amenable to computational analysis. So is it up to those in higher education to assure that students graduate with the ability to work effectively with data in their building projects? Tyler Goss, Director of Construction Solutions at Case Inc., believes it is. "There is not enough emphasis on the data-centric design approach in education." (Goss, 2014) Architects and educators are encouraged to use adaptable strategies organizations and universities can apply today to make the most of the data they have at their fingertips – much of which many may not be aware of. But it also calls attention to the trend toward a real-time convergence of technologies and processes that aren't reflected in linear first-this-now-this checklists. Forward-thinking research would do well to acknowledge and embrace this trend.

ACKNOWLEDGEMENTS

The quotations in this paper were adopted from interviews that originally took place with the author in 2014. The contributions of these design professionals and educators are gratefully acknowledged.

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