Adaptive and *Interactive* Metrics:
A hidden opportunity in design-for-sustainability

ROBERT J. KOESTER[1], SANDEEP ARORA[2]

[1]Ball State University, Muncie, USA
[2]MSKTD Architects, Ft. Wayne, USA

ABSTRACT: Responsible designers consider design a problem solving activity; they seek answers to questions as they work. But focusing on the formula-driven summative performance of "the problem" masks an opportunity. This paper borrows insights from nature to examine a new informational model of design-for-sustainability. The proposal is for a staged engagement of metrics—differentiating a structure of Adaptive and Interactive Metrics—to distinguish the universal from the particular when shaping design interventions. As nature teaches, it is the Adaptive and Interactive fit of a species with its environment that offers resilience in the face of the unexpected; and lays the foundations for the vast differentiation in the visual and operational fabric found throughout the natural world. This same complexity should be brought to architecture as we design-for-sustainability; wherein we can 'grow' design responses using the hidden opportunity by distinguishing both Adaptive and Interactive metrics.
KEYWORDS: Adaptive, Interactive, Metrics, Passive, Active

INTRODUCTION

Current engineering practice uses energy performance computer modeling of TMY (typical meteorological year) climate data to arrive at summative monthly and/or annual profiles of the thermal gains and losses through the building shell.

While this links to architectural strategies—e.g. the distinction of internal-load-dominated from envelope-load-dominated buildings—the practice is largely exclusionary. By reducing the architectural design challenge to summative energy performance (read balance of flows), we do not differentiate the ***Adaptive*** from the ***Interactive*** operational metrics.

Specifically, this distinction establishes the gradient up to which all buildings are universally performing equally and beyond which each building has particular climate-driven interactions. Employing ***Adaptive*** architectural design moves "below the gradient" and ***Interactive*** architectural design moves "above the gradient"—in the interstitial zones of the histogram—can clarify the untapped opportunities of design-for-sustainability.

CONTEXT

In light of the many international market trends, from the adoption of scoring systems such as LEED, BREEAM, and Green Globes, to the use of information management tools such as Building Information Modeling (BIM), to the continuing interest in user participation through Open Building Design, it is appropriate to distinguish ***Adaptive*** form ***Interactive*** performance as a means to reveal the rich structure inherent in the passive low energy design strategies of design-for-sustainability. Most importantly, this approach links the use of the metrics to the likely involvement of occupants; to optimize a building's climatic responsiveness by "sailing" the building.

THEORY

This theoretical approach can apply not only to the metrics of building form but also each of a building's environmental systems. This differentiation of ***Adaptive*** and ***Interactive*** Metrics can support the integrated design process; to structure stakeholder interaction. In addition, the process links to post-occupancy evaluation practices; providing a cross-referencing framework for the *indicative*, *investigative*, and *diagnostic* assessment of occupant interaction in, and satisfaction with, building performance.

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INFORMATION IN (OF) NATURE

Nature is form. Form is cellular. Form is mathematical. Form follows function. Such forms are expressions of internal and external force flows and transformation.

Numerous analyses of growth and form have been published including the works of Thompson [1], Bejan [2] and Darwin [3] among others.

Form in nature has been used as inspiration in the making of buildings. And while there are various movements in architecture that have used nature for that inspiration, there continues to be a missed recognition of a powerful opportunity in building design, which borrows from nature the ***Adaptive*** and ***Interactive*** analogy.

ADAPTIVE AND INTERACTIVE DISTINCTION

The ***Adaptive*** and ***Interactive*** characteristics of various species are fundamental to their identity, but more importantly talk to the complexity of environmental variability and performance response. The ***Adaptive*** and ***Interactive*** classifications talk to the deep structure of fit of a species with its environment—the broad feet of the camel to distribute weight upon the sand, the long neck of the giraffe to reach the trees, the fundamental geometry of the bird wing to develop lift for flight.

But within these basic orders of adaptive form, species also exhibit remarkable capacity and even resilience through their interactive behaviour. This interactivity is itself rooted in adaptive form such as the ability to manipulate a foot location or wing position, but also in the metabolics and surface characteristics of interactive thermal response. Establishing a thermal balance with the immediate environment is a complex process for not only both warm-blooded but also cold-blooded creatures. These adaptive and interactive characteristics, of course, translate readily to architecture as the passive and active classifications and scales of design response.

PASSIVE AND ACTIVE MEDIATION

These classifications can apply not only to the building form/organization—but also to the technological systems. As a classic example, the passive manipulation of sound signals in an amphitheatre or performance hall relies on the form of the architecture for the primary enhancement of the signal. A secondary manipulation of directionality and/or absorption—with band shell placement and/or the draping of walls with absorbent material is used to finesse the architecture of passive sound signal control. The use of active amplification systems then can supplement the first order passive design.

Passive and active mediation of course is more traditionally associated with strategies for solar energy collection in building design. The passive capture of the sun for space heating, water heating and/or electrical production is achievable through proportionality of aperture and storage material, orientation, and angles of exposure to the sun's pathways. The more active mediation involves the use of operable overhang elements, roller shades, the diffusion of collected heat energy with ventilation, or the mechanical tracking of the sun on its path. These observations are not new; they capture what has been studied for centuries in the practice of architecture. Even in the many writings of Vitruvius [4] the passive and active interventions were alluded to—if not scientifically annotated or understood.

The reason for this lengthy reflection, however, is to lay the foundation for the fundamental insight of this paper. Specifically, in this context, and out of the habit of our western mind, we continue to strive for a summing of exacting fit when in fact a hierarchy of responsiveness would offer a more complex capability for 'designing fit'.

MASK OF ENGINEERING FIT

Exacting fit is embedded in the calculation methodologies and emphases of typical engineering formulations. We try to optimize the use of a material to serve an engineering purpose and the formulations and methodologies by which we deduce our answers are well established. For example, the vector diagramming and free body analysis used in structural system design incorporates the fundamental understanding of strengths of materials; the introduction of surface reflection and beam control in lighting design incorporates an understanding of the physics of light; and the manipulation of the varying frequencies of sound signals incorporates an understanding of the difference in music and speech signal structure; these all are well understood at the level of fundamental engineering. Implicitly a responsible designer seeks a <u>perfect</u> fit.

MASK OF (VISUAL) DATA DISPLAY

With this sense of responsibility, we turn to the use of computing technology to emulate for example real-time thermal behaviour—taking into account the effect of climate variability, solar movement, wind, ambient temperature swings, internal loads (occupant, equipment and lighting), and the impact of space use scheduling variability, etc. These computing tools are validated for their predictability and reliability through testing protocols. In the end, of course, the designers recognize that they are using these tools in a closed-system function; comparing design iterations to an initial base case. The caveat always invoked is that the simulated performance is not guaranteed. Because of the variability of occupancy behaviour and other unknown factors, not to mention the care with which the building is actually constructed, the performance will not necessarily align with (fit) the prediction. Nonetheless, we find the graphic data display a useful tool for understanding the potential impact of each of the design iterations.

The difficulty, of course, is that the visual display is presented as a summative assessment of behaviour; and although some such software programs for example do differentiate thermal performance data of the histograms into the subset influence of opaque envelope, glazing, ventilation, internal load and solar exposure effects, we are still looking to the total energy flows as the basis for our decision making. We may well manipulate some components within the set of systems but we continue to focus on the grand total of impact as we compare each one of the design iterations to the next.

INTERSTITIAL ZONES

The first uncovering of the hidden opportunity in the use of ***Adaptive*** and ***Interactive*** metrics is to be found in the work of Ralph Knowles [5] who wrote about the significance of mathematical assessment and its alignment with observations in nature to determine the best fitting, least resistant profiling of urban form. This shaping of a solar envelope set the standard for passive solar design. His more recent book [6] introduced the design opportunity of interstitial space—the interstitium—between summer and winter solar envelopes.

Embedded in this simple concept is the realization that there is a fundamental adaptive geometry and an interactive surface fabric that can be used to account for the distinction of climate, summer to winter, and to make possible the increased use of occupant space without compromising solar access for neighbours. This concept of the interstitium, although shown by Knowles as an area for operational architectural features, can in fact be applied to the root illustration of graphic displays of the engineering performance data.

For any histogram or similar graphic display, one can readily determine that zone or boundary which is unchanging from each one of the iterations to the next. It is only the fringes (edges) of the number set that actually reflect a measurable difference—in energy consumption, illumination characteristics or acoustical behaviour, from one project to another, from one iteration to another. By acknowledging the distinction, we can find a primary and secondary hierarchy of architectural design response.

ADAPTIVE (PRIMARY) GESTURES

The primary adaptive gestures of any built fabric using this idea should be those tied to an unchanging climatic fit. No matter what the climate variability, the balance of flows will be unaltered. This can apply not only to a proportioning of built form but also to a selection of the armatures of built fabrics which are patterned for timeless fit to the environment. These would include the harvest of predictable force flows on site; water, wind, and sun.

INTERACTIVE (SECONDARY) RESOLUTIONS

The interactive fit of a proportioned built form with its climate is the zone of metrics in which elements and/or components can be placed upon the skin of the building or within the lining of a given room to effect the day-to-day performance of solar collection, thermal transfer, illumination control, or acoustical reflection; the elements are variable for purposes of user need—but especially variable and useful by users for their needs.

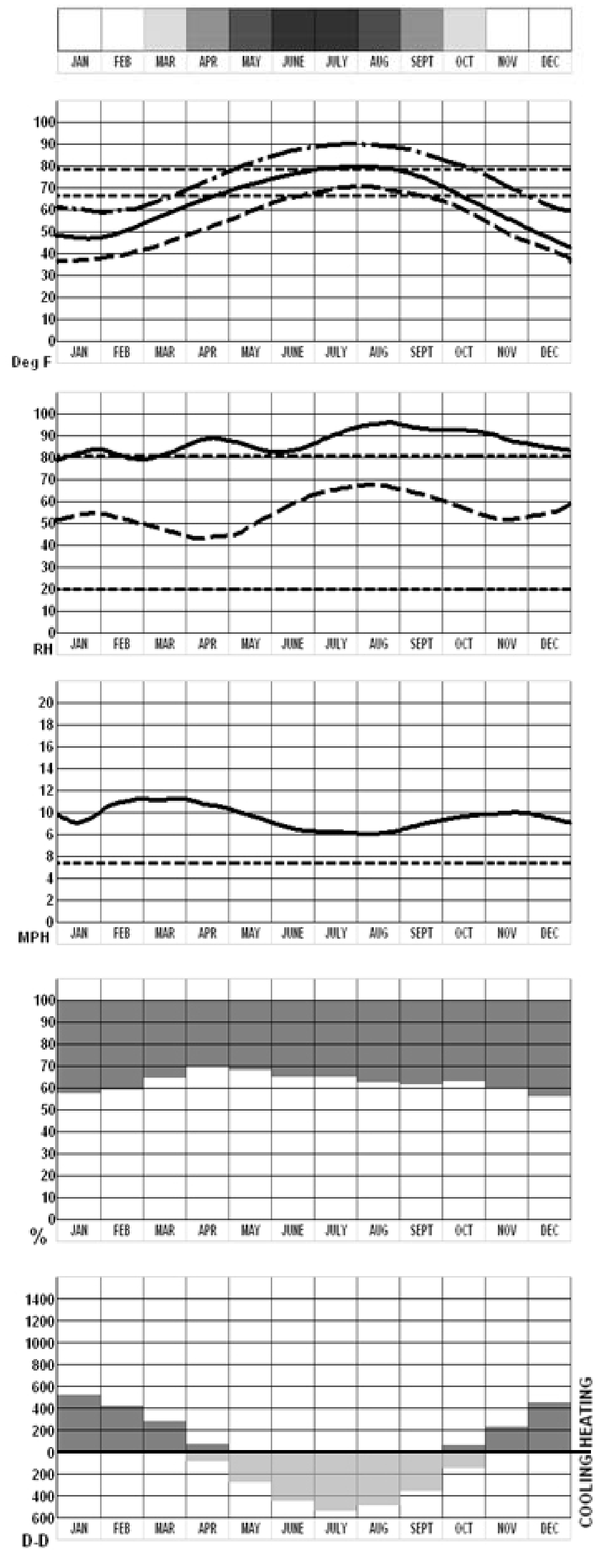

Figure 1: Typical Patterns of Climate Data Sets showing (in sequence) Overheated/Under heated times of year; Temperature Swings; Relative Humidity; Wind Speed Variability; Sunshine

Availability and the occurrence and magnitude of Heating Degree Days (HDD) and Cooling Degree Days (CDD)

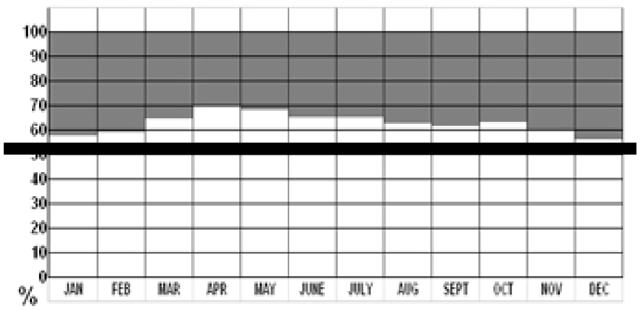

Figure 2: The Gradient of Adaptive and Interactive Metrics

PRE AND POST DISPLAY

Whatever factors are being considered in a project design, it is helpful to identify those summative data sets that pre-exist the design activity and those which result from it. The pre-existing data sets include harvestable natural resources and the influence of predictable occupant loads.

The resource harvests include water, wind, solar-thermal, solar-electric, daylighting, and a fully sustainable use of onsite (or near site) materials.

The predictable occupant loads include the many factors of indoor environmental quality—thermal, luminous and acoustic comfort, the need for water services and even food.

For the sake of illustration, this paper will use the pre and post summative data sets of climatic factors presented in Figure 1. *[More extensive content examples will be provided in the oral presentation of this paper.]*

The post display of summative data which occurs as a product of the design activity in the thermal example includes a profiling of energy flow through the building shell, the impact of internal loads from people, lights and equipment, and the strategies such as cross-ventilation, stack ventilation, solar thermal control and daylighting aspect.

CLIMATE DATASET

For the example of Figure 1, climate data can vary considerably over differing regions of the continental U.S. The conventional U.S. classification of climate conditions as hot-arid, hot-humid, temperate, or cool-moist suggests just such contiguous ranges. Of course within any given region, more complex differentiation is possible. Nonetheless in every case, it is possible to determine a gradient for bounding ***Adaptive*** and ***Interactive*** metrics.

As shown in Figure 2, the weighted effect of such delineation indicates those climatic conditions that are reasonably stable and those that are more volatile. Recognizing this factor, it is possible to strategically select the primary design intervention as an ***Adaptive*** response as distinct from a secondary ***Interactive*** mitigation.

Similar profiling of anticipated internal loads as shown can be used to bound the ***Adaptive*** and ***Interactive*** metrics as influenced by occupant density, occupant activity and time of use patterns.

A simple comparison of internal loads against climate loads hints at the internal-load or skin-load dominated nature of a project. More importantly, the bounding of the ***Adaptive*** and ***Interactive*** metrics yields anchor points from which to operate in choosing design strategies.

POST DISPLAY OF DATA

The histograms of performance resulting from specific design strategy limitation, as shown in Figure 3 reveal the nature of interaction between climate influence and internal loads. The breakdown of these summative histograms clarifies the rank order influence of differing elements of building performance—the influence of the opaque and glazed surfaces of the envelope, the impact of ventilation/infiltration and the role of solar thermal transmission. It is helpful however to separate those parts of the subset histograms that comprise the fixed and unavoidable adaptive fit from those zones which are the more dynamically interactive; ***Adaptive*** from ***Interactive***.

COMPLEXITIES OF CONCEPT

In principle the introduction of a gradient for weach load that defines a boundary between the ***Adaptive*** and ***Interactive*** zones of summative engineering data is rather simple. However once the boundary has been introduced, the pattern and dynamic variability of the interstitial zone of the interactive data set lays the groundwork for a rich conversation about design intervention. Depending upon the frequency, magnitudes and the ranges of variability in the interstitial data sets, interactive design intervention can be fairly simple or will require multiple layers of interactive control. This more substantial complexity resulting from the initial simplification brings new structure to the conversation about active and passive design and more particularly design-for-sustainability.

TIME-DEPENDENT PROCESS

Design itself is a time-dependent process requiring multiple cycles of iteration. In that sense, it mimics the teachings of nature in which trial and error development and resolution of environmental fit at both the ***Adaptive*** and ***Interactive*** levels have led to the evolution of such diversity of species worldwide. Although nature operates on a millennial time scale, the principle of the balance-seeking process is nonetheless applicable in the tight time constraints of an architectural project. Certainly invoking participation by the team of design professionals and stakeholders can be made more effective by the clarity of

Adaptive and ***Interactive*** data sets as presented in this paper.

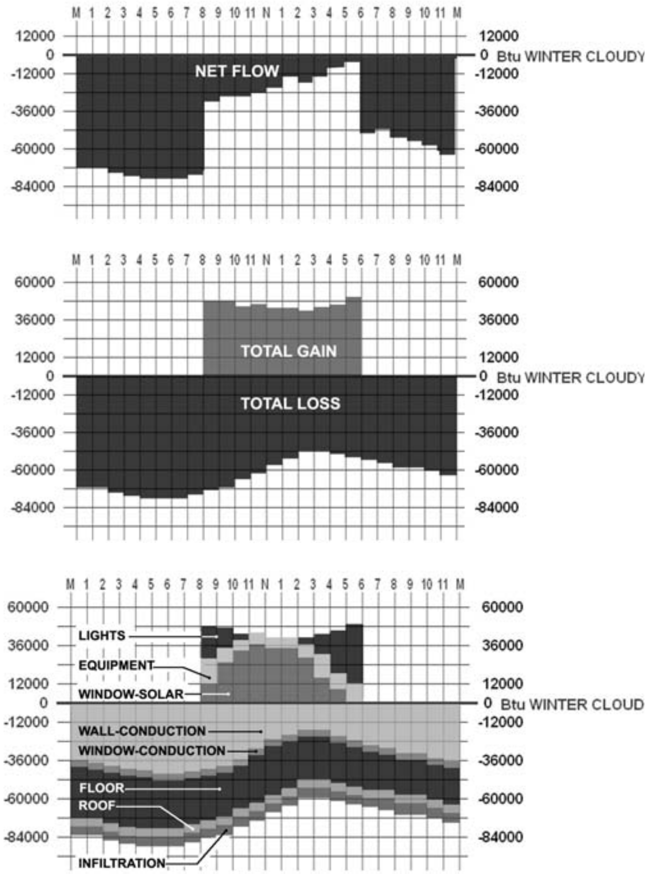

Figure 3: The Subsets of Energy Balance

LEED/BREAM/GREEN GLOBES

These three scoring systems which have transformed the marketplace of design and construction offer useful organization for the conversation by participants in a project. However the nature of a checklist is to imply an oversimplification of the complexity of an effective design project. Design-for-sustainability requires not only the iterative looping of decision making mentioned above and can benefit from the categorical structure of scoring systems cited here, but also is much better when informed by an overarching system that distinguishes the timeless from the moment-of-time characteristics of architectural intervention. The ***Adaptive*** and ***Interactive*** metrics discussed in this paper help to clarify that distinction.

BIM

Building Information Modelling is another significant influence in the current marketplace. The obvious arguments put forward in favour of such computing tools are the resolution of conflict in a virtual world prior to the start of construction. The ***Adaptive*** and ***Interactive*** metrics discussed in this paper provide another layer of information and useful influence in the application of BIM techniques. Early construction of electronic models in BIM can be based on the ***Adaptive*** performance factors; the subsequent layering of decision resolutions can occur as the design team works to finesse the ***Interactive*** interventions for design response.

OPEN BUILDING

In similar fashion, the hierarchy of ***Adaptive*** and ***Interactive*** performance can fit well with the principles of open building which differentiates at least five scales of time-based decision making. The open building distinction of urban tissue, base-building, partitioning fit-out, and furnishings and equipment can relate directly to the ***Adaptive*** and ***Interactive*** metrics. The base-building should be one that is adaptively suited to its climate. The fit-out can comprise those layers of materiality that provide for interactive climatic fit.

CONCLUSION

The rather simple concept of introducing a gradient boundary to distinguish the ***Adaptive*** and ***Interactive*** metrics of engineering performance opens wide-ranging conversation about design strategy. This concept offers promise to the design team in that early agreement can be achieved when the task at hand is to size, proportion or otherwise configure, a base-building to meet the fixed and unavoidable force flows and balances of a building form and technical systems in a given climate. Having arrived at such early agreement, the more subtle and complex articulations needed to fit the ***Interactive*** metrics of project to site/climate can account for the uniqueness of occupant load and occupant interaction as well as the fine-tuning of the summative data sets for the project.

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