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Dimensions of Use: From Determinism to a New Humanism

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Abstract

Dimension—the measure of extent—is the technical means and manifestation of human use embedded in architecture. Beginning in the Enlightenment, the proportional relationships between humans and architectural dimension evolved into precise measurements, becoming by the modern era indicators of efficiency, performance, and standardization. Today, the architectural dimension has become deterministic; driven by stringent codes, standards, and benchmarks tied to building program. Divorced from their originating logics and consequences on human occupation, the dimensional standards and requirements abstract people into loads or clearances that separate buildings from human experience and use. Examining dimension’s entanglement with practice and technology to provide shelter for human use illuminates the ways architecture has been thought about and the ways it is used over time. By tracing the changing concepts, metrics, standards, and technologies of architectural measurement, this article reveals the sometimes overlooked or disconnected values and considerations of *use* in the theory of architectural technology. This research points towards critical approaches to design based on human use, extending building performance beyond quantitative metrics towards an architectural dimension of inhabitation; one that avoids standardization and reasserts human users as the measure of building.

Keywords

Dimension, Function, Humanism, Use, Program

Critical histories and architectural dimensions

Architecture mediates physical relationships between people and their constructed environment, connecting human uses with the formal, spatial, and tectonic performance through acts of demarcation—through dimension. Whether assessed by human perception and experience (composition, perspective) or objectively evaluated with technology

(performance, conformance), architecture relies on measurement—the “comparison with some standard, such as measure, scale, or the human body” (Johnson 1994, 349–351)—to develop a set of ideal, optimized, precise dimensional relationships. The mediating function of dimension to translate ideas into physical buildings lies at the core of architectural practice, and it is the practical and theoretical connections to human use that can distinguish architectural dimensions from those in other disciplines, such as sculpture and construction.

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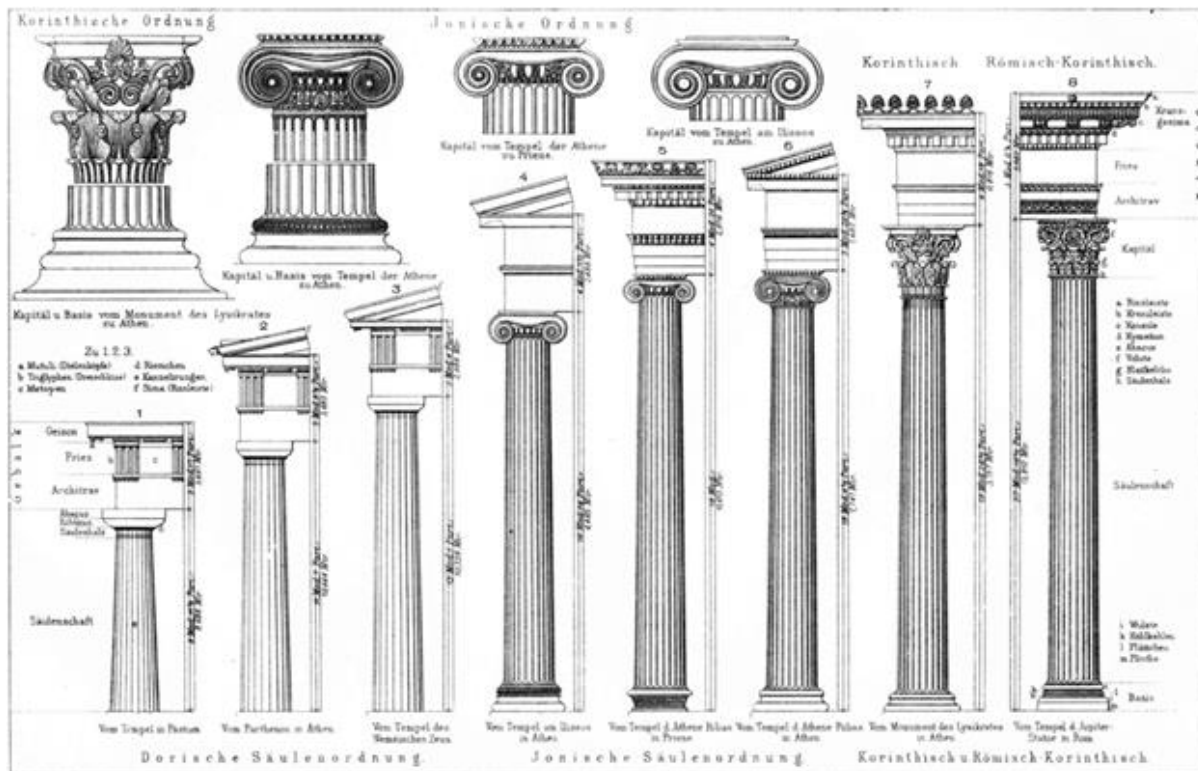


Figure 1: The classical orders illustrating proportional relationships based on empirical measurement of particular buildings listed below each example. This plate reproduced from Meyers Kleines Konversationslexikon. ("Baukunst" 1892, 194).

This article traces the evolution of architectural dimensioning from its proportional roots through the pragmatic service of modernism, to the ultimately deterministic application enabled by codification and standardization. Exploring dimension's entanglement with practice and technology reveals its influence on the utility, cultural value, and human experience of space—making it an important socio-technical device for long-term human use. The following sections describe the origins, evolution, and the ongoing reassessment of the abstraction that reduces the human condition to standard dimensions and quantitative metrics. A critical theory of technology for the architectural dimension must be grounded equally in the ethical and pragmatic considerations of economy, providing frameworks for architects to understand, negotiate and integrate more critically metrics of cost, material and spatial efficiency, tolerances for fabrication and assembly, and other intangible factors of human use. This critical reexamination is currently taking place in many approaches to practice that are generative of

architectural order and invites a deeper inquiry of programming's functional approach.

The Natural Dimension

The Cosmic Order of Natural Proportions

Early civilizations relied on anthropocentric measurements. Even when units of measure existed, early architectural thought and practice relied less on the specific units than on proportions—the relative measure of elements typically found in whole-number ratios—as both technical and theoretical means (Figure 1). In part, this stemmed from the limitations of the tools available. Walker and Tolpin describe artisans' use of manual dividers to understand proportions in nature and to project their own ideas onto buildings and objects without recourse to systems of units, arguing that "measurements as we know them in a modern sense were largely unknown and unnecessary." (Walker and

Tolpin 2013, 10–11) Such proportional measuring systems would continue through the Renaissance, with the Egyptians, Greeks, and Romans all developing standard units in relation to the human body such as the finger, palm, foot, cubit and fathom. (Tavernor 2007, 22) Naturally, these units were standard only within relatively constrained geographic areas, and their definitions varied from one region or time to another; for example the cubit has a short version of anthropological origin, as well as a longer, architectural definition found in the Near East in pyramidal documents and scripture. (Stone 2014) Vitruvius—whose writing in the first century BC is the oldest existent account of western architecture—identifies the idealized human body as the appropriate source of dimensions to interpret, for example, the size of the earth which was to be understood through “the strides that humankind made upon its surface, and its great extents was understood relative to the size and upright actions of our bodies.” (quoted in Tavernor 2007, 19) Such humanistic dimensions are likely universal as, in his seminal work *The Hidden Dimension*, anthropologist Edward Hall observes that across all cultures, the size of spaces are fundamental to their *kinesthetic* experience, and notes the importance of measuring horizontal dimensions in paces, and vertical dimensions by reach, saying: “What you can do in it determines how you experience a given space.” (E. T. Hall 1990, 54)

Renaissance artists and architects rediscovered, expanded, and systematized the classical relationships between bodies and buildings. Rudolf Wittkower (1952) demonstrated how Francesco di Giorgio Martini and Leonardo da Vinci applied the Vitruvian human-body-based proportional system to the geometries of centralized-plan churches, (Figure 2) writing: “this man-created harmony was a visible echo of a celestial and universally valid harmony.” By adopting human proportions as static measurements, this approach changed the Vitruvian kinesthetic sense of the human body moving through space to an intellectual experience of architectural proportions that combines visual perception of building elements with cognitive appreciation of an abstracted rational order.

For his part, Renaissance architect and humanist author Leon Battista Alberti asserted that dimensions and proportions derived from observations of nature. (Johnson 1994) Alberti interpreted the proportional, whole-number geometries of ancient Roman

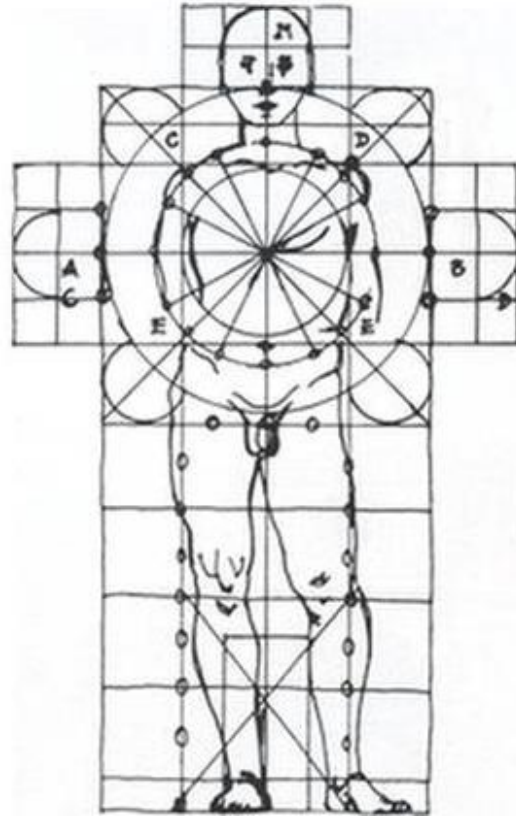


Figure 2: The search for architectural proportion in the human form. Plan of a basilica by Francesco di Giorgio Martini (1481–1489) *Trattato d'Architettura*, from the *Codex Magliabechiano* in the archives of the *Biblioteca Nazionale Centrale di Firenze*.

architecture as part of the lineamenta, “the line,” understood cognitively as part of an architectural order quite separate from the tangible material of architecture. (Hendrix 2011)

Similarly, humanist philosopher Francesco Giorgi asserted Pythagorean and Platonic relationships between numbers and cosmic order in musical scales. The sixteenth century architect, Palladio developed systems of proportion relating rooms in plan. (Wittkower 1952) These mathematical abstractions emerged in early architectural theory to represent the unity between art and science, geometry and symbolism. (Wittkower 1952) Such relationships continue to fascinate: in the twentieth century, Colin Rowe compared Le Corbusier’s purist Villa Garches and Palladio’s Villa Malcontenta, (see Figure 3) proposing a shared mathematical standard of “natural beauty,” and identifying different

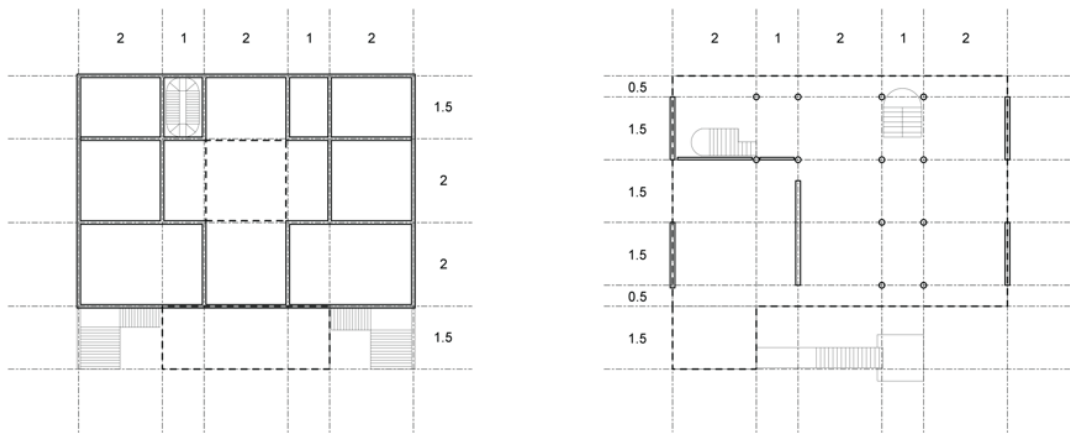


Figure 3: Comparison of plans for Villa Malcontenta (left) by Palladio and Villa Garches by Le Corbusier (right). Drawing by authors based on the analytical diagram by Colin Rowe in *The Mathematics of the Ideal Villa* (Cambridge: MIT Press, 1982); recreated for clarity and to overlay additional information.

approaches but similar confidence in an objective basis for aesthetics. Palladio considered this a “projection of the harmony of the universe,” while Le Corbusier described as *des vérités réconfortantes* (of comforting truths). (Rowe 1982, 2–17) Thus each era and culture’s system of measures simultaneously follows from and illuminates its understanding of architectural dimensions, echoing Evan’s observations about the link between architecture and representational techniques. (Evans 2000)

Dimensions of Environmental Performance

The relationship between the human body and dimensions is not abstract: it embodies performative relationships. Philip Noble describes architecture as a contingent art and suggests that contextual factors help guide proper proportional responses. (Holden 2012) Amid these contextual factors of structure and environment, proportion has quantifiable impacts on building performance, architectural expression, and human use.

Some classical architectural proportions evince multidimensional performance that facilitates use by harmonizing physical form with the climate to afford environmental control with few or no power-operated systems. Physical proportions—relationships rather than dimensions—shape the flows of heat, light, and air in, around and through buildings. The relationships embodied in vernacular

and classical buildings—although sometimes validated and expressed in modern dimensional means—are evidence of nuanced climate response in historical buildings and contemporary practice. For example, cultures in hot climates around the world adopted courtyard-forms; adjusting the aspect ratio and depth to balance solar control and passive ventilation. Conversely, many cold-climate indigenous buildings—from the igloo to the gar to the tipi—adopt round or nearly-round plan shapes which maximize useable space for a given enclosure and equalize distance from a central heat source. In these examples, the form and geometry derive from the constraints of physics; even without a mathematical understanding of the underlying principles. In a counter example, early digital architecture eschewed physical constraints like gravity or human experience in pursuit of pure formalism, prompting a reactionary “second wave” that attempted to ground digital form by adopting mathematical expressions of natural phenomena. (Wallisser 2009, 93) So-called minimal surfaces enclose the greatest volume with the least surface area, conserving material while reducing conductive heat transfer through the envelope (Faghih and Bahadori 2011) and limiting exposure to solar radiation. (Marsh 2006).

These principles operate at smaller scales as well: relationships among building components evince complex performative relationships. For example, indigenous builders calibrated wall thickness and material heat capacity with the diurnal temperature

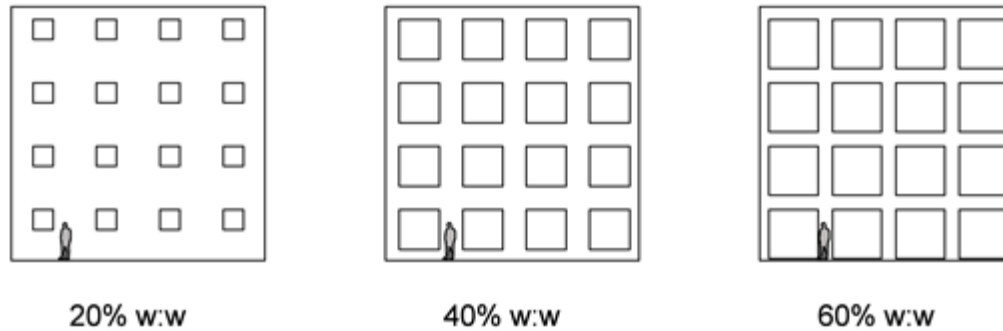


Figure 4: Illustration of the ratio of fenestration to opaque envelope, or Window to Wall Ratio, is a common dimension of envelope performance. 40% is often used in prescriptive criteria. Drawing by authors.

range to provide thermal comfort by absorbing heat in the day and releasing it at night. Too little thermal capacity would overheat the interior before the sun sets, while too much capacity would prevent the heat reaching the interior by evening and precludes fully discharging the stored energy overnight. In a modern example, reducing the ratio of fenestration to opaque wall—the so-called Window to Wall Ratio (WWR) shown in Figure 4—generally reduces thermal loads as fenestration is typically a poor insulator, except limiting windows may adversely affect daylighting and views for occupants. (Troup *et al.* 2018) While classical proportions governed the fenestration in part for material and structural limitations, modern building regulations may limit the WWR for thermal and energy-conservation purposes.

Other considerations of context, interior access to the façade, climate, and exposure also influence or even dictate proportions, and the integration and interaction of these complex and dynamic systems gives rise to ultimate built form. For example, while the solar control of direct beam sunlight is a strictly geometric proposition relating buildings to the sun, daylighting for interior illumination and comfort presents a more complex problem of multiple reflections and potentially diffuse light from the sky and surrounding environment. Prior to the advent of reliable electric illumination, architecture was necessarily designed around daylight proportions and human perception. Christoph Reinhart cataloged different versions of the ubiquitous Daylighting Rule of Thumb (DRT)—which relates the depth of the usefully illuminated floor to the height of the window

(Figure 5) and evaluated them through simulation across a range of variables. His findings support the notion that the depth of useful illumination will extend between 1.5 and 2.5 times the height of the window head into the floor. Interestingly, the forms and proportions of good daylighting often work well for natural ventilation also. Natural ventilation by either internal stratification (stack effect) or capturing external movement (cross ventilation) depends on adequate pressure differences to overcome turbulence and friction. As shown in Figure 5, ASHRAE guidelines for natural ventilation suggest the depth of a space should be not more than five times its height for double-sided (cross) ventilation, and no more than twice the height for single-sided ventilation. (ASHRAE 2016a, sec. 6.4.1) In spite of the codification, proportions of performance also have limitations: airflow is not guaranteed, and the mindless application of the DRT risks over-lighting the area near the window and causing glare throughout in the room. Modern practice may still employ the empirical proportions, but also verifies dimensions of environmental performance through detailed testing and measurement in service of human experience, perhaps following Louis Khan's dictum that "A great building must begin with the unmeasurable, must go through measurable means when it is being designed and in the end must be unmeasurable." (Kahn 1961, 149) These examples suggest the multivariate, occasionally contradictory, and complex nature of dimensional and performative parameters in architectural design for human use.

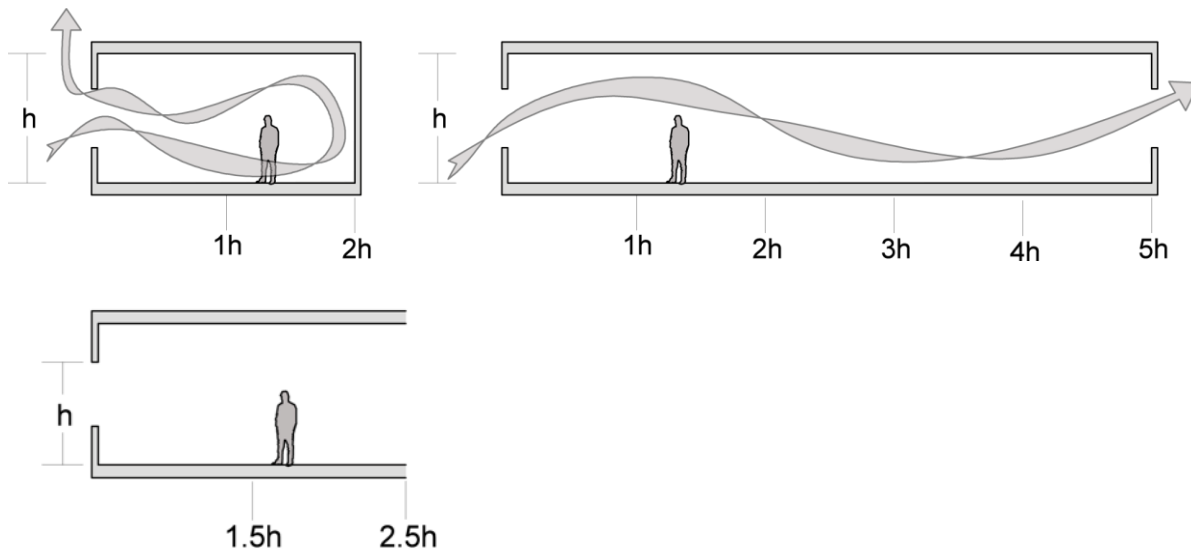


Figure 5: Performance, in this case effective one- and two-sided ventilation (above), is geometrically proportional to ceiling height; while the useful penetration of daylight (above), is geometrically proportional to window height. Drawing by authors.

Proportions no longer represent mystical and symbolic connections to the cosmos, leading Paul-Alan Johnson to remark, “Proportion has been entrenched in architecture for so long that it has come as a shock to find that if the proportionate ratios of the traditional kind are ignored, nothing nasty happens.” (Johnson 1994, 371) Yet the relationships embedded in these proportions of environmental performance continue to relate physical buildings to the flows and laws of the natural universe, and continue to be valid, increasingly well-understood, and even suggested as a basis for contemporary sustainable design. (Lechner 2001, 9)

The Pragmatic Dimension

The Evolution of Units and Metrics

Where *proportion* was the standard of the classical era, increasing rationalism demanded precise *measurement* with new standards and tools. Alberto Pérez Gómez, no stranger to issues of geometry and proportion, suggests that western thought began reconciling formal and transcendental dimensions during the Galilean revolution circa 1600, achieving the true divorce of faith and reason in the 1800s. By this time, Newtonian science and non-Euclidean geometry unleashed an era of conceptual and

material efficiencies, prompting a “functionalized theory subsumed by technology,” (Pérez Gómez 1983, 238–239) which in architecture resulted in the technical control of dimensions through quantified loads and material properties. The metric system—as radical a product of the French Enlightenment as the French Revolution itself—enabled and signified this change by replacing the king’s foot as unit of measure. Instead of symbolic proportions or anthropocentric dimensions, precise scientific measurements based on logical inquiry and reflecting “the new understanding of the mechanical universe—the natural rhythm of time as the earth rotates daily on its axis, and annually around the sun,” (Tavernor 2007, 72–83) were equally available to all. Applying the new rationalist measurements in his position at the new École Polytechnique in the early nineteenth century, J. N. L. Durand transformed architectural education to essentially eschew the human body. In his *Précis: des leçons d'architecture*, (Jean-Nicolas-Louis Durand 1985) Durand removed human references from the systems of proportion, replacing them with abstract standards based on social utility, efficiency, economy, Cartesian geometry and material logics, as shown in

Figure 6. (Tavernor 2007, 107–112)

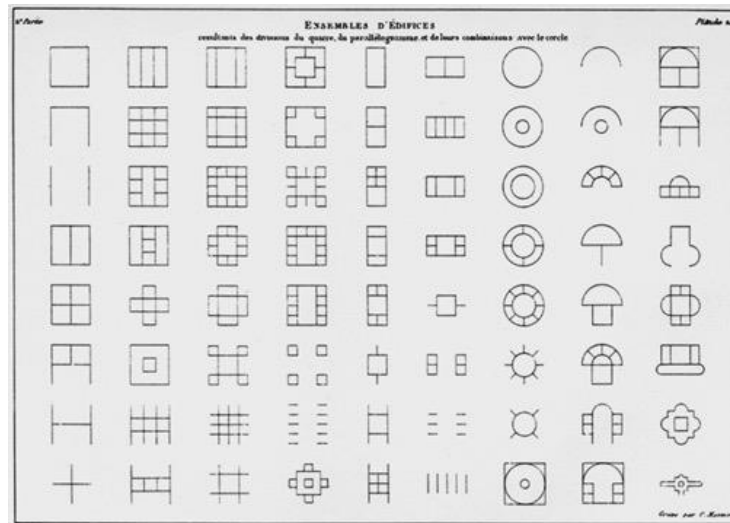


Figure 6: Plate 20 *Ensembles d'Édifices* from J. N. L. Durand's *Précis des leçons d'architecture données à l'École impériale Polytechnique* (Jean-Nicolas-Louis Durand 1985). It is assumed that each one of these geometrical figures are abstractions of one or more buildings, which Durand categorized according to function. (Madrazo 1994). This image from *Plates to Précis, Part II: Composition*, reprinted courtesy of Yale University Library in translation (Jean-Nicolas-Louis Durand 2000).

The course of such impersonal spatial logic reached an apex one-and-a-half centuries later, when Leslie Martin appropriated Durand's functional typologies to promote research-based design of mathematically ideal density, economic and environmental performance for formal building types. Although this effort influenced generations of sourcebooks like "The Metric Handbook" and "The Architect's Pocket Book," (Dutoit, Odgers, and Sharr 2010) it did not necessarily produce humane architecture since, as Adam Sharr observes, "obsessions with perfected function ignore the functional redundancy that is often the grit in the oyster making for deliciously unquantifiable delight." (Sharr 2010)

Furthermore, increasingly scientific approaches tended to separate building production from the core of architecture through the proliferation of disciplines. Figures like Jean Prouvé led a shift towards architectural engineering in the twentieth century. Henry Cowan—who in the mid-twentieth century helped establish the field of architectural science and published multiple books outlining the history of science in architecture—lamented that the Masters of Modern Architecture proclaimed the importance of science and technology but without a sound knowledge of building science or a holistic view of technology. (Cowan 1966; Cowan 1977; Cowan 1978) Abrogating the technical dimension freed

architects to focus on buildings as objects, rather than human experience or consequences. In response, Cowan founded the first graduate program in architectural science (a program he compared and contrasted to Architectural Engineering) calling for better methods to predict the physical behavior of buildings, the social response of people, and to integrate these findings into design. (Cowan 1980) These appeals mostly led to increased specialization, rather than integration, reducing the complexity of human experience to single dimensions, supported by specialized and isolated regimes of measurement. As explained in the following sections, it is not surprising that the dominant themes over the course of the industrial revolution and the rise of capitalistic economics reduced the rich and complex humanistic dimension to metrics, loads, and codes based on pragmatic considerations.

Dimensions of Structural Efficiency

Following classical conceptions of virtue, architecture originally embraced sufficiency and economy of dimension as aesthetic and ethical mandates. For example, Alberti described the architects' duty "to prescribe an appropriate place, exact numbers, a proper scale, and a graceful order for whole buildings and for each of their constituent parts," asserting "it is wrong to make either the width or the height of a

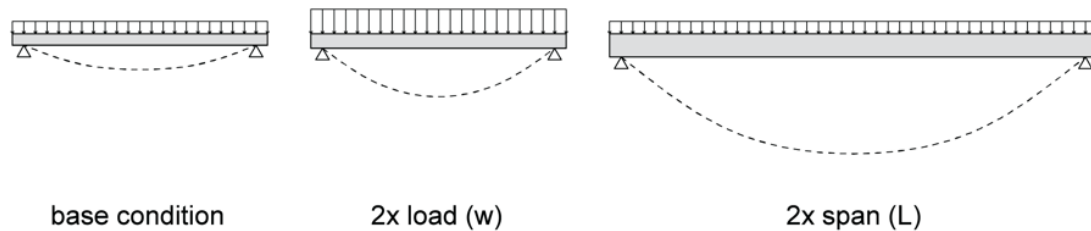


Figure 7: Relationship of span, load, and maximum bending moment in simply-supported, uniformly-loaded beams. Drawing by authors.

wall greater or less than reason and scale demand.” (Johnson 1994, 362) Art historian Arnold Hauser attributes these virtues of *sufficiency* and *economy* to a “scientific conception of art,” a conception still present in modern ideas like biomimicry, but which he claims began with Alberti, who was “the first to express the idea that mathematics is the common ground of art and the sciences, as both the theory of proportions and the theory of perspective are mathematical disciplines...the first to give clear expression to that union of the experimental technician and the observing artist.” (Hauser 1999) In contrast to Alberti’s fifteenth century ethical focus on artistic economy, Pérez Gómez claimed that the complete “mathematization of theory” in architecture originated with the seventeenth and eighteenth centuries’ focus on statics and strength of materials as the rational drivers of form; yielding a simplicity provable through mathematics, and avoiding the excess caused when classical architecture mistakenly transposed primitive wooden forms into stone or marble. (Pérez Gómez 1983, 244–253) Whatever the origin, this rationalist focus, and the corollary application of quantitative assessment to buildings, unleashed our present era of engineering economy and expectations of efficiency in buildings, with undeniable benefits but also some cost.

This application of rational engineering principles to architecture prompted quantitative approaches to dimension and scale, the development of scientific understanding of structures, and structurally efficient designs. One metric of structural performance is maximizing useful span for the minimum material used, goals often coupled to, though not synonymous with, assumptions of least economic and environmental cost. Efficiency requires both seeking

lighter, stronger, and less expensive materials, and configuring them most effectively. In structures, material thickness (tectonic dimension) and span (spatial dimension) have a simple, direct proportional relationship: longer spans demand thicker materials, and together, these elements establish the basic armature for patterns of material use. Figure 7, and equation 1—the maximum bending moment of a uniformly-loaded simply-supported beam—illustrate the precise mathematical relationship of material and space.

$$\text{Eq. 1: } M = \frac{wL^2}{8}$$

Mathematically, the load (w) has a smaller effect on the bending moment (M), and therefore on the overall depth of the member than the span (L). Thus, the dimension and pattern of spatial use-configurations exert greater influence on structural thickness, and floor-to-floor heights, than the load.

In structural design, efficiency is defined as the ratio of loads supported to the weight of the structure (Eq. 2), this relationship may become an objective function, seeking the “optimal” structure that supports the maximum load with the lowest quantity of structural material. Engineered structures that consider only this single dimension of optimization may be designed for economy by fixing design loads at the lowest possible requirement and minimizing the structural material for those loads. Structures designed for economy also generally adopt repetitive patterns, using similar components and assembly processes borrowed from a Fordist model of industry.

Frequent points of vertical structure require smaller structural elements, increasing beneficial redundancy but reducing flexibility for use configurations. Less frequent points of vertical support require longer structural spans, resulting in deeper material thickness and reduced redundancy, but potentially increasing use configurations. As a corollary to equation 1, code-defined loads can establish the required capacity and designers then optimize the structural spacing or span to that particular occupancy or function.

$$\text{Eq. 2: Structural efficiency} = \frac{\text{Loads supported (lb or kg)}}{\text{Weight of structure (lb or kg)}}$$

Structural efficiency is one of many ways in which engineering rationalism influenced architectural theory. It was precisely while teaching engineers in nineteenth century France that Durand developed his major works, applying principles of scientific classification systems to geometric genres or typologies largely based on function, and to the compositional principles that combined modular components to the systematization of architectural knowledge. (Madrazo 1994) The mandates for economy, efficiency, and optimization evolved with the technological advances of the nineteenth century industrialization, through twentieth century automation, and ultimately to twenty-first century algorithmic systemization. Each technological advance promised—and sometimes even provided—lower cost and therefore greater democratic access to good architecture, thereby enhancing the quality of life for all. However, the purity of reason and the perfection of technology also become ends unto themselves rather than tools to advance architecture toward more human-centric environments. When the limits of available technology become the standards for architectural production, the optimal may well replace the good.

Dimensions of Profit

Where the classical canons identified virtue in achieving the *mean* of neither excess nor deficiency, (Johnson 1994, 349–51) and structural efficiency followed rules of physics and material science, the commodification of the built environment defined *economic* efficiency as a ratio of maximum space to minimum cost, setting design quality in opposition to profit, particularly in types like speculative office buildings. Of particular concern is the ratio between “assignable” area and the necessary but unprofitable space for services, circulation and the like. Organizations like the Building Owners and Managers Association (BOMA) aimed to “keep costs down, create more revenue, and coordinate labor” by establishing quality and efficiency metrics “normalized” per unit of area. (Goedken 2007) Metrics for rent, sales, productivity, and the like became drivers of architectural production, adhering to measurement-centric management theories while ignoring the importance of the unmeasurable¹ and Goodhart’s so-called law, which suggests that once a measure becomes a target, it ceases to be a good measure. (Manheim and Garrabrant 2018) These new quantitative metrics replaced humans with numerical representations of selected human characteristics, reducing learning to test scores, humans to variously-productive users, and sensory experience to computational models. Architects’ perception that attending to these metrics result in monotony and repetition justified their willingness to relinquish responsibility over them to specialists and consultants: that loss combined with the architect’s waning control over means and methods of construction, gave contractors power over projects. (Smith 2011) Architectural dimensions are inevitably connected to these market-driven metrics of profit and cost efficiency, criteria that Tim Love says seek “the maximum number of hospital beds, hotel rooms, or condominiums for the smallest amount of circulation space.” (Love 2004, 42–47) Perhaps inevitably, many parts of the building industry adopted the economic-industrial model of mass production to reduce cost and (ideally) increase quality. As developed by Ford in the automotive

¹ A selective quotation from W. Edwards Deming, that “if you can’t measure it, you can’t manage it” sometimes accompanies these assertions of the primacy of quantitative measurement. In fact, Deming

made *precisely* the opposite argument: his full sentence reads “It is wrong to suppose that if you can’t measure it, you can’t manage it – a costly myth.” (2000, 35)

industry, the mass-production model depends on predictability and repetition of elements and tasks to reduce time and waste. (Smith 2011, 10–12) This transition from *making* to *manufacturing* also marked (and was enabled by) a dramatic shift in the use of dimension, from proportions in three-dimensional space to compositions of two-dimensional representations: the triumph of dimensions made for machines, rather than human eyes and hands. (Walker and Tolpin 2013, 11) Such manufacturing logics were the basis for “the notion of the architect as a prototype designer, the house as a consumer product, and the building trades as a unified industry entirely focused on off-site production,” and presented aesthetic and performance challenges when factory tolerances were incompatible with site assembly (Rupnik 2012). New technologies of digital measuring, design, and production promise to solve tolerance problems, increase design and production quality, and reduce cost. (Smith 2011) While these digital technologies continue to transform practice, architectural theory continues to grapple with the commodification of the built environment and the deterministic role of economic metrics.

The Deterministic Dimension

Working from an anthropological perspective (and without precluding factors such as climate and culture), Edward Hall explored buildings—from their subdivision into rooms to their groupings in villages and cities—as expressions of the social-spatial organization of people. Although subdivisions of interior space are longstanding, their assignment by function is a recent phenomenon dating only from the eighteenth century, before which rooms were used as needed. Hall credits the advent of the corridor—which allowed for privacy, social class segregation, and sanitation—with developing new patterns for family structure and asserting a reciprocal relationship between social relationships and the built environment, (E. T. Hall 1990, 103–102) just as zoning later developed new patterns of community structure. Starting from an architectural rather than anthropological perspective, Robin Evans arrived at the same conclusion: contrasting the matrices of connected rooms typical before the nineteenth century with the advent of the corridor plan. Evans describes how new attitudes made carnality distasteful, leading architecture to limit encounters

and friction of bodies, thus creating “the logic now buried in regulations, codes, design methods and rules-of-thumb” that still dictate contemporary design practices. (Evans 1997, 85–86) Where the dimensions and disposition of building elements traditionally negotiated scale, so as to “effect the connection between the person and the building,” (Johnson 1994, 363) these same tools became instruments to separate human bodies in and from buildings.

The Rise and Fall of Functionalism

Hall’s and Evan’s anthropological and architectural studies point to an important, nineteenth-century shift towards what might be dubbed *functionalist* architecture, one that physically embodies and indeed enforces social structures by fixing dimensions in space, separating human activities, and adhering to increasingly rigid laws or rules. Stanford Anderson describes functionalism as “an untenable position,” (Anderson 1987) however, the following exploration of *program* as a generator of architecture—particularly the regulation of form and dimension by code—suggests functionalism plays a deterministic role in much contemporary architecture.

Although sometimes used interchangeably, there are critical distinctions between function and human use. *Use* describes the act of employing something to the individual habits or group customs, and to the privilege or benefit of using something; it is, in other words, intrinsic to the person. (Merriam-Webster.com 2017a) In contrast, *function* describes the action for which a person or thing is specially fitted or used for; in other words an instrumental or mathematical correspondence. (Merriam-Webster.com 2017b) So functionalism, in this context, describes optimizing space for that activity for which the building (or part of a building) is especially well suited. For designers, achieving suitability for purpose closely aligns with the architectural task of *programming*. At its best, the programming process wrests clear goals, requirements, and criteria from a chaos of unformed desires thus defining the problems that will be solved through design. Program is a powerful tool for advancing architectural planning, but offers as many limitations as advantages (McMorrough 2006), not least because the notion of building function has

plentiful problems in theory.² For example, Louis Sullivan's often misquoted late nineteenth-century axiom that "form ever follows function," (Sullivan 1896), derived from his close observations of nature, so the dictates of Sullivan's "law" suggested that unchanging functions in a building must adopt natural forms with inherent dimensional qualities, hence the middle spaces in tall office buildings reflecting what Sullivan dubbed "loftiness." (Sullivan 1896, 406) The difficulty of program-as-design-generator are also quite legible in overly-deterministic buildings. For example, the functionally-expressive forms of raked theaters projecting from Melnikov's Rusakov Club (1927) and the village of rooms in Gehry's Winton Guesthouse (1987). The problems are equally visible in buildings for which program has insufficient formal power—or is itself indeterminate—which necessarily yield banal and generic buildings like the big boxes of "flexible" retail. The more pervasive problem with the quantitative approach of programming, as explained in the following sections, is its influence on the critical dimensions of the architectural project through the direct connection to the term "occupancy," which is repeatedly used in codes to define loads and clearances that fix minimum or required dimensions.

Dimensions of Loads and Clearances

The technology of dimension allows architects to generalize, simplify, and aggregate humans and human activity to unidimensional *loads* defined primarily by function or program. For example, occupancy loads, live loads, internal thermal loads; each possess their own hidden histories and logics, and each accounts for only one aspect of the human person. As described previously, these loads translate directly into the design of the object (the building morphology) and systems (parts individually dimensioned but interconnected to create a whole) and serve to simplify design decisions through generalization. However, by eliminating the nuance and complexity of specific humans in the interest of programmatic clarity, such loads do not necessarily support continued human use. (Herdeg 1983) Modernism's notion of open space allowed fluid spatial configurations loosely organized by a Cartesian-gridded structural pattern, defined by

ephemeral non-structural partitions enclosed within the light boundary of the envelope. In contrast with the functionalist narrative about form, (Anderson 1987) it was Modernism's technological emphasis on function and efficiency as drivers of spatial and tectonic dimensions that enabled program to become deterministic.

Programmatic standards are literally codified: contemporary codes and standards dictate acceptable dimensions for the arrangement and size of whole buildings and the parts within them to protect public health, safety, and welfare. Although seemingly objective and technocratic, such standards are never neutral, and while these thresholds yield significant good, they also enable new avenues of mediocrity, which hold the merely acceptable as sufficient, and then enshrines it as the objective for optimization. Erwine decries such misapplication of codes and standards in contemporary practice, describing a process "stalled at the level of commodity with nothing to say about delight." (2016, 12) Maximum heights, number of stories, floor areas, and minimum separations are all governed in codes by construction type and occupancy. Occupancy loads are organized by function, not so much to ensure the provision of adequate personal space, but to calculate a total occupancy (number of people per room) and dimension egress paths for life safety. For example, in the International Building Code the requirement of 15 ft² (1.39 m²) per person in assembly occupancies defines the load, and the provision of 0.2 inches (5mm) per occupant sets the width of the egress corridors. (International Code Council 2014) For similar reasons, modern building regulations define the live loads that floors must carry based on occupancy or function of the space, codifying with few modification the values defined in the first publications by Schneider in early twentieth century. (American Society of Civil Engineers 2010) Given these load values, calculations like equation 1 dictate the consequences of defining the minimum safe span or spacing of vertical structural elements to enable the possible forms of human use, which result in the largest impact on bending moment, and thus on structural depth. In this and many other ways, the initial program selection determines the dimensions

² For an extended discussion of issues with architectural programming, including Peña's programming method, see (Moe 2013)

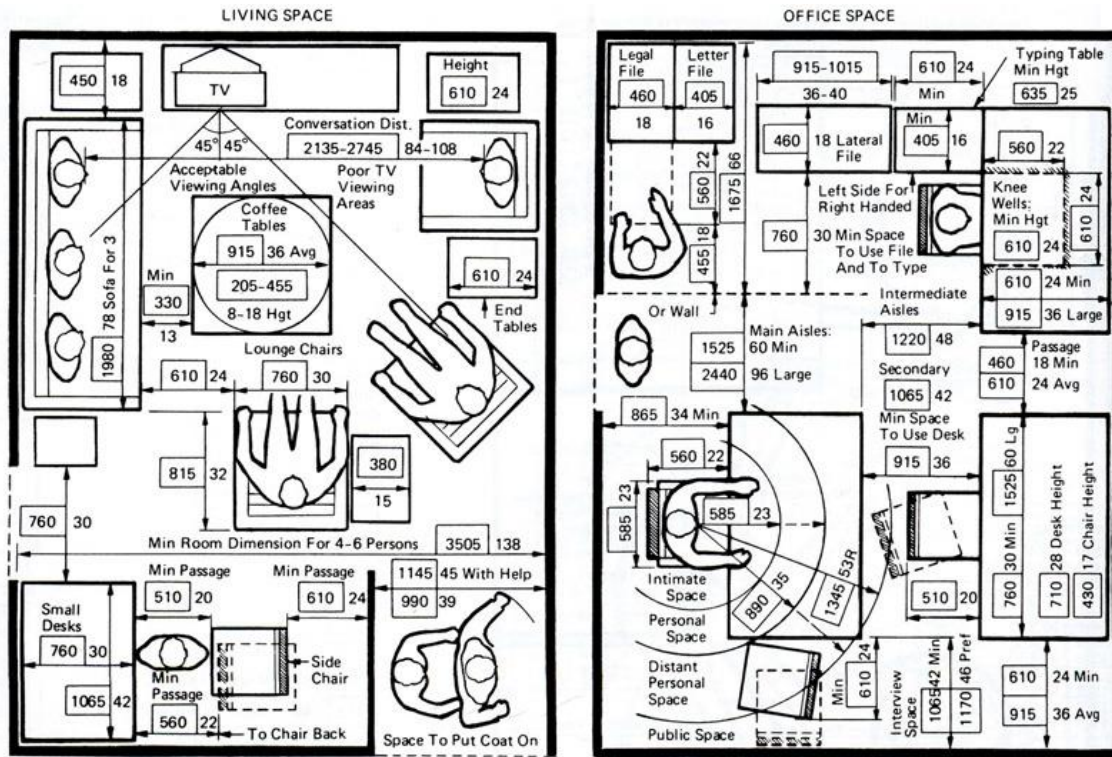


Figure 8: Clearances for accessibility originally drawn by Niels Diffrient, and Alvin R. Tilley of Henry Dreyfuss Associates New York. Published in *Architectural Graphic Standards* (2000) by Wiley & Sons. Used with permission: license 4476140111489.

of buildings, its structural components, and rooms, doors and corridors. Similarly, the sizes of mechanical and plumbing systems are determined largely by program, occupant heating loads, ventilation rates, and building areas, all regulated to protect public health, and all conspiring to reduce those humans to a volume of fresh air, a quantity of heat gain, or a plumbing fixture count.

Critically, the converse relationship is equally—and perhaps more permanently—deterministic. Once a depth and span are established, the live load, and therefore the possible uses for the space, are also constrained. Avoiding programmatic determinacy—or achieving long-term use-adaptability—may require designing for excess demand (e.g., greater density of people, higher live loads) than the code-minimum for the initial program. As minimum standards, no code prohibits *additional* capacity for egress or structural strength, however, adding capacity beyond minimum requirements reduces initial structural and economic efficiency and requires initiative and justification. In

what might be dubbed *reciprocal functionalist determinism*, programmatic decisions define the dimensions of buildings, and then those dimensions effectively reify that program into the fabric of the built environment for the long term.

Fulfilling the functionalist imperative, by determining the physical relationships among people and between people and objects, codified building dimensions establish cultural relationships as well. Hall dubs this the *cultural dimension*, and identifies its reciprocal influence, saying, “The relationship between man and the cultural dimension is one in which both man and his environment participate in molding each other.” (E. T. Hall 1990, 4) In a 1943 speech, Winston Churchill offered the pithy formulation of such reciprocal influence, saying “We shape our buildings, and afterwards our buildings shape us.” (Churchill 1943) Minimum *clearances*—the dimension between components to accommodate installation, movement, or access (Ballast 1994, 269) as shown in

Figure 8—and programmatic *adjacencies*, have come to define many human-architecture relationships in the planning, distribution, and allocation of space. (Reinhart 2005) Granting its practical necessity, clearance as a minimum provision of space is a curious mechanism by which to define relationships: one based on enforced separation between people and their environment, rather than their closeness. For example, significant architectural moments predating such regulation, such as Wright’s famously low entry ceilings and the ramp at Villa Savoye exhibit the power of intimate sensory experience using approaches that would not satisfy current codes. Design can also mandate interpersonal clearances: for access and hygiene, modern standards for early childhood facilities establish a minimum three-foot separation vertically or horizontally between children lying on mats or cots: yielding layouts designed to divide and separate even innocent social interactions for at least part of the day. (American Academy of Pediatrics, American Public Health Association, and National Resource Center for Health and Safety in Child Care and Early Education 2017, 5.4.5.1) Adjacency, while perhaps less isolating, collapses a range of nuanced relationships between parts to mere spatial proximity or minimal dimension. Yet together, clearance and adjacency enshrine program in the spatial dimension, thereby, creating the social dimension and enforcing particular patterns of human use.

While all architecture inherently embodies or represents cultural values and ideologies, which can be interpreted and appropriated, the coercive social power of codes and standards can regulate dimension to actively concretize social structures, such that the evolution of building codes provide an “index of changing social values and at the same time a strategy to enforce those values.” (Moore and Wilson 2012) The congressional findings establishing the Americans with Disabilities Act of 1990 (ADA) explicitly recognized the power of the built environment to manifest and enforce particular social dynamics, noting “the discriminatory effects of architectural, transportation, and communication barriers.” (Americans with Disabilities Act of 1990 1990, vol. 42, sec. 2) The Design Standards stipulated by ADA

establish a set of minimum dimensional requirements for building design to ensure individuals with disabilities can access and use public, commercial and government facilities. These dimensional building blocks—for example, the provision of sufficient clearance for wheelchairs—in turn provide sufficient space for all users, but not necessarily ideal space for any of them. (American Institute of Architects 2016, 42) These standards dramatically changed the built environment over the past quarter-century. Peacock et al. count the influence on and of the built environment as a success, noting “Since the passage of the ADA, there have been extensive gains in access to public services, the built environment (e.g., crosswalks with curb cuts for wheelchair access and accessible pedestrian signals to assist people who are blind or have low vision), and attitudes toward and understanding of the abilities of people with disabilities.” (Peacock, Iezzoni, and Harkin 2015) Ironically, the codification of accessibility, although it creates a new architectural order available to a broader population, also reduces a diverse human population to standardized dimensions based on early human measurement and ergonomics.

By codifying the dimensions necessary to ensure the health, safety and accessibility of the built environment, modern regulations and standards replace complex patterns of human use with programmatically-determined *dimensions*. In part because they take the form of minimum thresholds rather than absolute prescriptions, these dimensions attract scant critical attention in their role as progenitors. However, absent critical understanding of their originating logics, trade-offs and effects on human occupation, the dimensional requirements embedded in codes are abstractions of people separated from human experience and use; indeed Moore and Wilson suggest that rules and codes are internalized by forgetting the reason of their making. (2012). For example, widespread design practice slopes ramps at the code-maximum 1:12, even though accessibility depends on the effects of the ramp design on particular populations, rather than the ramp slope alone, and so even this slope does not ensure universal access. (Sanford, Story, and Jones 1997, 23)³ Even in the service of human values such

³ These authors found that 15% of manual wheelchair users had difficulty traversing a thirty-foot-long ramp with 1:12 slope. Based on the constraints of their research design and method, the authors believe this

figure *under*-represents the portion of the total wheelchair-using population affected, and cite prior findings that between 12% and 70% of wheelchair users *cannot* navigate the codified 1:12 slope. With laudable

as equal access, the dimensional codification is not necessarily humane, the application of these abstracted dimensions demands conscientious humanism.

Toward a Humane Dimension

Dimensions of Human Experience

Alvar Aalto criticized contemporary modernist architecture (and architects) for being functional chiefly from a technical point of view, and suggested that a truly functional architecture must be functional from the human point of view. (Aalto 1998) For Aalto this meant an architecture that enlarges technical functionalism with psychophysical phenomena was better for all human senses. Edward Hall, in developing his own theory about the human use of space, arrived at a similar conclusion when he observed that technological innovations like the wheel, language and mathematics extend human functions and capabilities beyond the limitations of physiology and biology, prompting a new reality in which human tools replace nature. (E. T. Hall 1990, 4) The lexical proposal to acknowledge the effects of human intervention on the planet by designating a new human-dominated epoch—the Anthropocene—lends new urgency to the call for a new humanism, suggesting that human interventions in the environment are neither necessarily intentional nor benign. (Waters et al. 2016) This argument shows, the many practical and theoretical reasons to abandon the reductionism that disposes humans as simply measurements of loads and clearances. New critical approaches should engage a broader territory of dimensionality and are, in fact, beginning to do so.

Universal Design emerged from a critical architectural stance and the evolving cultural attitudes about disability over the past century—from protective paternalism, to accessibility as a civil right, to modern conceptions of universality—and seeks to provide a more holistic and human-centered approach. Architectural Graphic standards notes, “Public accessibility standards establish general design

specifications that broadly accommodate minimal needs... It is also likely that people with disabilities will appreciate universal design approaches because they improve function beyond minimum requirements and increase social participation and safety.” (American Institute of Architects 2016, 39) The potential for greater human satisfaction and superior architecture that transcends legal minimums and better addresses the diversity of people must start as Monica Ponce de Leon says, “by acknowledging that we all have different degrees of abilities.” (Ponce de Leon 2010)

The advent of *performance-based design* in the late twentieth century represents a similar critical approach and marks a transition back to providing for human needs. Performance-based design focuses on what a building does for human beings, rather than prescribing the materials, measures, and methods of its construction, in short “the performance approach is no more than the application of rigorous analysis and scientific method to the study of the functioning of buildings and their parts.” (Working Commission W60 1982, 1). Rather than simply applying formulaic requirements, performance-based standards use code requirements as a threshold against which to test performance. Restoring code to its rightful place and adopting the process of *falsification* characteristic of science, increases design freedom. Modern codes increasingly include performative as well as prescriptive methods of compliance. For example, in the area of energy and sustainability, the performative approach focuses on reducing environmental impacts and ensuring human health and comfort, rather than achieving prescribed interior conditions using specific equipment. Designs comply by demonstrating performance superior to a *baseline*—an utterly-deterministic, minimally-compliant theoretical version of the building. (ASHRAE 2016b)

An as-yet undefined critical approach appears to be coalescing around the emerging interest in resilience in design disciplines, and particularly in models of socio-ecological resilience, which reject the notion of a single equilibrium or optimization for current loads, and instead support robustness and redundancy. Rather than optimizing space for immediate functions

understatement, the authors note a lack of consensus, and the wide range of both steeper and shallower recommendations for the *optimal* slope.

or an initially deterministic program, designers can develop performance criteria and dimensional qualities that support active human use or inhabitation over time. This alternative concept for multiple-equilibria may define the parameters—and dimensions—of a truly resilient building. In fact, building resilience in architecture has been defined in opposition to engineering’s functionalist approach, which prioritizes a return-to-function in disaster-recovery by instead focusing on the resilience inherent to the natural and cultural structures where human beings thrive over time. (Laboy and Fannon 2016)

Pérez Gómez observed that our quantitative gain in life expectancy—a product of advances in medicine and in the design of the physical environment—is “the most powerful and unquestioned argument on behalf of the superiority of our technological ways,” but he contends that it can also limit the architect’s “traditional role, contributing to the psychosomatic health of society.” (Pérez Gómez 2016, 6) Growing interest in evidence-based strategies for health in the built environment represents an opportunity to re-examine the architectural dimensions of human well-being and comfort, building on a decades-long movement to assert the importance of sensation and experience, perhaps best illustrated in thermal environments. Since the advent of air conditioning, the conventional approach to the thermal environmental strove for undifferentiated consistency, neutralizing the environment to what James Marston Fitch described as “a thermal ‘steady-state’ across time and a thermal equilibrium across space.” (Fitch and Bobenhausen 1999) These attempts to achieve consistent thermal conditions in a constant manufactured environment—by seeking to eliminate all thermal stress—mistake the absence of discomfort for comfort itself, and gave rise to architectural dimensions based on program, divorced from bioclimatic response and human inhabitation, demanding vast quantities of energy and depriving humans of the richness and pleasure of thermal diversity. Our mechanistic model of comfort produces “spaces that are everywhere the same and nowhere special—environments that are acceptable but not inspiring, comfortable but not comforting, predictable but not memorable.” (Erwine 2016, 12) A wide and deep body of work about human thermal comfort challenges this neutrality, with seminal contributions from both the scholarship of design (Heschong 1979) and engineering. (de Dear and

Brager 1998) Michelle Addington draws on this work to examine the notion of the human body in a neutral or steady space, criticizing the focus on technologically-advanced envelopes to compensate for poor formal and material choices, and expands her critique by focusing on the architectural dimension of the thermal zone. (Addington 2009) Holistic and adaptive models tune the thermal dimension by including human physiological and psychological factors: e.g., salutogenics, biophilia, and alliesthesia to create comfort and delight. (Mazuch 2017) (Parkinson and De Dear 2014) Decades after Lisa Heschong challenged designers to strive for thermal delight rather than mere satisfaction, these approaches are making inroads, as witnessed by the 2004 adoption of the adaptive model into ASHRAE comfort standards. Of course architectural experiences involve more than thermal sensation, as Pallasmaa notes “Instead of mere vision, or the five classical senses, architecture involves several realms of sensory experience which interact and fuse into each other.” (Pallasmaa 2012, 45) Perhaps more deeply understanding the sensory and sensual qualities of architecture will displace the standardization of technical provisions for physiological conditions and return the discourse of *phenomenology* to architecture. Inspired by the ideas of Bachelard, Heidegger and others, phenomenology explores the impact of temporality and materiality on the human senses and memory, (Bachelard 1969; Heidegger 1996) offering architecture new dimensions of human perception, consciousness, emotion, and authenticity.

Towards an Architecture of Use

Invoking *use* in architecture inherently posits people as the subject, not the object, of that architecture. The everyday lexicon of architectural practice generally treats the terms *use*, *function*, and *program* as interchangeable, ignoring critical distinctions. *Function* frames people as objects of activity contained in the architecture, while *program* is defined by floor area requirements and efficient adjacencies, which reduce inhabitants to mere metrics. As shown in this article, even though buildings are relatively long-lived, programming commonly fixes dimensions based on the near term without regard for the multi-generational duration of buildings. Stewart Brand neatly describes this

dilemma, noting that, “The great vice of programming is that it over-responds to the immediate needs of the immediate users, leaving future users out of the picture, making the building all too optimal to the present and maladaptive for the future.” (Brand 1995) Human use, however, is not devoid of quantitative measure: it is enabled or inhibited by the inextricable spatio-tectonic duality now and over time. Use embodies both the activities that take place in a space and the user who engages in them. Therefore, the metrics of use are inclusive: they align the quantitative and the qualitative attributes of an architecture with the inhabitant. Juhani Pallasmaa writes: “Human use and specific purposefulness is constitutive of the art of building. Architecture arises from purpose, not from a desire to make an aesthetic object.” (Pallasmaa 2014) Pallasmaa’s *purposeful* architecture acknowledges the dynamic lives that unfold within buildings. An architecture of purpose—or use—that is generated by the performative criteria of a building’s inhabitants instead of by disembodied metrics suggests a new type of humanism. Dietmar Eberle sees such a new performative humanism as the ultimate measure of architecture, noting that, “History teaches us that buildings need to be robust. Robust refers to the materiality of the building and its simplicity, but also to the architectural qualities of the building: arrangement and dimension of the rooms, daylight—the ability to provide comfort and well-being. This type of robustness guarantees a long life for the building instead of assigning the users a kind of compulsory happiness.” (Eberle and Aicher 2016) Physical dimensions tend to be the most persistent attributes of architecture. Only when design processes imagine the effect of dimension on human use can architecture fuse the physical and the performative, making human users as the measure of a “robust” architecture. By embracing the quantitative, qualitative and temporal dimensions of human use, architects can challenge the dimensionally-deterministic limitations of contemporary practice to promote a long-term and humane architecture.

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