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*Full Length Research Paper*

# Modeling relative influence of environmental and socio-cultural factors on context-specific functions

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**Traditional models in building physics are based on theories in physics and physiology, typically characterized by a-contextual settings and domain-specific articulations. It is, however, commonly understood and appreciated that physics and physiology, alone, do not entirely explain observed patterns of user behavior in buildings-in-use, and that people do not experience various aspects of a setting in isolation. This study at the Georgia Institute of Technology, using Post-Occupancy Evaluation (POE) data from 26 courtrooms, developed a set of models that: 1) integrated variables from multiple domains, 2) developed a smaller set of aggregated functional dimensions intuitive to building stake-holders, 3) were context specific, 4) captured instrumental as well as abstract functions, and 5) articulated the relative influence of variables on the aggregated outcome measures. POEs started as a methodology to provide user input in building design and has expanded to a practice that incorporates user feedback along with technical and financial performance. Starting with one-off studies during the late 1960s, POEs have expanded considerably in terms of building types, tools, methods, and scope. The POE data in this study included physical, environmental, as well as user attribute data. Physical and environmental data were collected using scientific instruments widely accepted in the building evaluation community. User evaluations of the courtrooms on multiple dimensions were collected using 7-point ordinal scale measures. Environmental and user attribute data were regressed on aggregated performance dimensions (resulting from Principal Component Analyses) to arrive at the integrated models, presented in this paper. The authors argue that the modeling approach supplements the traditional paradigm in two ways: 1) by validating traditional building physics models, and 2) by enabling validation from the clients' perspective, focused on higher-level functional requirements.**

**Keywords:** Building Performance, Integrated Models, Post-occupancy Evaluation.

## INTRODUCTION

The dependence on axiomatic/ normative models in building physics in predicting performance of targeted functions in built settings represents an important missed opportunity. It could be argued that traditional building physics is characterized by:

- Dependence on theories in physics and physiology.
- Development of models based on studies in controlled environments and standard users.
- Modeling isolated spheres of environmental parameters (such as, models predicting outcomes in the isolated domains of heat, light, etc.).

Integrated into building codes and guidelines (thermal, acoustical, lighting, etc.), the dissociated manner in which knowledge built into such models inform stakeholders of built settings represents the typical paradigm of practice.

It is, however, commonly understood and appreciated that people do not experience various aspects of a setting in isolation, which is increasingly getting translated into multi-domain research work in building physics that develop integrated models of performance outcomes in designed settings. For instance, several studies have inv-

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estigated performance (problem solving, cognitive tasks) and the influence of (a combination of) luminous, auditory and thermal variables on human performance. Most studies have reported significant association bet-ween one or more of the environmental variables on various outcome measures of interest. To illustrate a few, noise and illuminance have been shown to influence free recall tasks (Hygge and Knez, 2001). Similarly, noise and luminance influence feeling of fatigue (Takahasi et al., 2001). Other studies show that spectral quality of light, and noise, impair cognitive performance (Knez and Hygge, 2002). Noise and temperature, combined, have been shown to influence the subject's perception of thermal comfort (Pellerin and Candas, 2003). These and other studies provide evidence that the association between user behavior and environmental parameters may not be stratified.

While integration of multiple domains in single models constitutes an important variation in modeling strategy, two related issues warrant attention. First, like traditional models, the integrated models cited above are characterized by controlled environments and standard users. This translates to modeling efforts where variances arising out of factors other than the limited ones being studied are controlled (or not allowed to change). Such factors could also include organizational, individual/ personal, or cultural ones. This is of particular interest since numerous literature articulate potential problems associated with ecological validity (Winkel, 1987) in the development of models in controlled/ contrived settings–i.e., constructs measured in controlled environments may not correspond with constructs in non-contrived (buildings-in-use) settings, which are essentially the target of the prediction models.

A second area warranting attention relates to the outcome being measured. Typical outcomes predicted by traditional models (as well as the integrated ones cited above) pose two issues. First, many traditional studies involve the use of contrived tasks (such as memory recall, response time, visual acuity in extreme conditions; Boff and Lincoln, 1988a,b; this should be read differently from contrived settings) that may or may not correspond to tasks performed in actual settings. Second, although traditional modeling efforts have been gearing towards model validation involving more realistic outcome measures, stakeholders (building users and owners) of built settings are increasingly focusing more on higher-level (more aggregated) performance outcomes. For instance, measuring the influence of illuminance conditions on reading printed texts in classrooms constitute, from a stakeholders' viewpoint, only an intermediary objective towards more aggregated measure of how well students learn, or how engaging the teacher-student pedagogic relationships are. That, in turn, requires integrated modeling approaches that offer the potential of aggregated outcome measures intuitively appealing to building stakeholders, in a specific context.

## A-Contextual generality versus contextual functional specificity

The authors argue that developing integrated, aggregated models for context-specific predictions constitutes a direction of inquiry that could significantly supplement the utility of traditional models. The major strength of traditional models lies in the generality of application that transcends across setting types and time. Supplemental predictions on how designed environments influence the functions (performance) in specific settings with specific users in a known context could enhance decision making in facility procurement and management in many ways, a few of which are outlined in the concluding paragraphs.

Developing context specific models, however, is conditional on several issues. The most important condition is that data from buildings-in-use be available, without which the question of context specificity would be difficult to address. A second issue relates to developing aggregated measures that are meaningful and relevant to building stakeholders. A final issue relates to identifying relevant data types that, together, display evidence of predicting the aggregated outcome measure of interest.

Data from buildings-in-use, lately, are increasingly being available from Post-Occupancy Evaluations (POEs) or Building Performance Evaluations (BPEs; a more recent development, denoting an expanded scope of building evaluation). POE started as a methodology to provide user input and has expanded to a practice that incorporates user feedback along with technical and financial performance. Starting with one-off studies during the late 1960s (Preiser, 2001), initial efforts were focused on solving problems related to housing needs of disadvantaged people and improving the quality of public housing (Vischer, 2001). The 1970s witnessed major expansions in POE studies. Courthouses, prisons and hospitals were targeted for evaluation (Vischer, 2001). During the same period offices and schools were beginning to be targeted by POE researchers in the Great Britain (Preiser et al., 1988). The period, on the whole, witnessed an adoption of research methods and tools from diverse fields in POE, and embraced a wide variety of building and occupant types for systematic study. The large body of knowledge, generated in the process, led to the development of a number of design guides and standards (Preiser, 1994). The progress during the 1970s helped POE develop into a discipline on its own right during the 1980s, with an established net-work of researchers, a developing corpus of knowledge, and a bag of accepted research tools and methods (Preiser et al., 1988; Zimring and Reizenstein, 1980). The 1980s also attracted the attention of the private sector, and occupant satisfaction surveys were conducted in numerous offices, schools and hospitals. The energy crisis of the 1970s, and the subsequent thrust in building component manufacturers towards developing energy efficient systems, led to the expansion of POEs into domains of energy use and occupant comfort (Vischer, 2001). The developing corpus of knowledge, methods, and expertise resulted in some other outcomes too. During the 1990's POE tools and data were considered appropriate to develop accountability measures. Joiner (1996) discusses the growth of POE in New Zealand, where it introduced new measures of performance by demanding ways of demonstrating that the designed settings work well for the users and building managers. Since then, POE has emerged in New Zealand as a process offering social negotiation between stakeholders of a building project. Other contemporary developments in POE include the process-oriented approach pro-pounded by Preiser (1996) that also examines influential economic, political, social and regulatory factors that impact the outcome of a building procurement cycle.

Today, POEs are regularly being conducted in large client organizations with or without extensive building portfolios. Some examples of such organizations include the US General Services Administration (such as, CBE, 2001), the US Courts (such as, AOUSC, undated), United States Postal Services (such as, USPS, 1996), etc. With the first premise satisfied elaboration of the two subsequent tasks form the primary emphasis of this paper.

## THE STUDY

This paper draws on a Georgia Tech study where POE data from 93 courtroom users in twenty six trial courtrooms in the United States were used. Two kinds of data were collected. One type relates to the as-built description of the settings, including dimensional attributes, and factors in the visual, auditory, and thermal environments. Instruments widely accepted in the building evaluation community were used to measure as-built attributes of the courtrooms. The instruments included:

1) Leica Geosystem's DISTO$^{TM}$ pro$^{4}$a infrared device and a conventional measuring tape for measuring physical dimensions,
2) EXTECH Instrument's Temperature/Humidity meter for recording temperature and humidity data,
3) Larson Davis 800B for acoustical measurements,
4) Minolta CS-100 Luminance Meter for recording luminance values, and
5) EXTECH Instrument's Foot Candle/Lux Meter for measuring illuminance values.

All measurement procedures were standardized for data reliability, and data was recorded on a standardized as-built data-recording sheet. The second set of data was evaluative, where users rated the degree to which the setting supported specific courtroom functions. Users rated their environment on an ordinal scale ranging from 1 (least supportive) to 7 (most supportive) on a range of courtroom tasks. A standardized survey form was created for recording user ratings, which also included items to record user attributes. Forty three types of as-built physical and environmental data were collected from each site on the standardized data collection protocol. In addition, through survey questionnaire six types of user attributes, and 27 evaluation data was collected (see Pati, 2005, for more details of the study). In essence, each evaluation data collected in the POE study had a range of corresponding objective physical and environ-mental data as hypothesized correlates.

Courtrooms were considered merely as a test case, and the approach outlined in this paper is applicable in other settings. Moreover, courtrooms posed a well-constrained space with a range of complex and con-flicting functions that are both instrumental as well as abstract in nature. The range of data collected in the study was based on an earlier ethnographic study by the author (Pati, 2005) that suggested five principal/ critical requirements in courtroom settings for conducting trial proceedings:

- The ability to see clearly and perform visual tasks.
- The ability to hear clearly when spoken to by other people and the ability to discuss issues with others without being overheard, in many circum-stances.
- The ability to perform each phase of the proceeding without undue disturbance or obstructions arising from dimensional attributes-smoothness of task flow.
- Portray the symbolic importance of the setting.
- Ensure safety and security of all people, proceedings / function, and objects (such as evidence) throughout the trial proceedings.

The central focus of the POE evaluation was on the extent to which courtroom environment supported particular courtroom functions. Owing to matters of logistics, security issues were kept outside the purview of the study. Two main classes of analytical techniques were used to develop models that articulate relative influence of environmental and socio-cultural factors on aggregated context-specific functions. The first step constituted developing the aggregated outcome measures, which is elaborated next.

### Developing aggregated measures

The attempt towards identifying aggregated outcome measures was founded on the assertion that two or more grass root level tasks (such as, reading from printed documents, listening to witness testimony, etc) could cluster together to share a common desired range of environmental supportiveness in actual settings. In contrast to controlled studies, in actual settings, people rarely perform singular tasks in isolation. Thus, a judge in a courtroom could read legal documents, take notes, and listen to the lawyers' disposition simultaneously. The question addressed by this step of the inquiry is whether two or more of the tasks in non-contrived situations cluster together into meaningful aggregated chunks, sharing a common set of environmental parameters as influencing factors, and a common range of parameter settings

**Table 1.** Outcome of Principal Component Analysis showing rotated component matrix of variables related to visual tasks.

| Outcome measures | Brief explanation of measurement | Component | |
|---|---|---|---|
| | | 1 | 2 |
| Reading Task | Reading from printed documents – including legal documents | .773 | .267 |
| Reading from screen | Reading from computer monitors | .861 | .165 |
| Writing/typing task | Taking notes, filling forms, cataloging evidence, using computer keyboard | .833 | .166 |
| Examine evidence | Examining evidence | .883 | .299 |
| Observe faces-well | Faces in Well - judge, deputy, reporter, jury, attorney, witness | .217 | .813 |
| Observe faces-gallery | Faces in Gallery - potential jurors, attorneys, witnesses, defendants | .489 | .606 |
| Sightline obstructions | Arising from courtroom elements (furniture, equipment) and people | -.116 | -.782 |

for optimal performance. The main analytical tool used for identifying potential clusters was principal component analysis. The different outcome measures from the POEs were subjected to a series of principal component analyses using Varimax rotation. The resultant components suggested a lesser number of aggregated performance dimensions intuitive to court-room stakeholders, which are discussed next.

Seven variables were related to courtroom functions in the visual domain. Result of principal component analysis, using Varimax rotation, suggested two underlying aggregated dimensions/ components, which are presented in Table 1. The total variance explained by the two components is 70.96%. A closer study of the two components makes it obvious that the first four variables contribute mostly to the first component, and the last three variables to the second component. The two components also have intuitive appeal. The first component relates to variables associated with tasks that are performed on one's immediate desktop. The second component relates more to tasks that are generally not desktop related, and are performed across the courtroom, such as observing the face of witnesses in the courtroom well (well constitutes the area in a courtroom distinct from the spectator's gallery) or potential jurors seated in the gallery, and obstructions of sightlines caused owing to courtroom furniture and/or people and lighting conditions.

It is noteworthy that although reading from printed documents as opposed to computer monitors are treated as separate grass root level tasks in controlled studies, such activities in courtroom settings tend to cluster together. Similarly, both tasks involving computer monitors and reading faces of witnesses, for instance, involve tasks on the vertical plane. However, in courtrooms the tasks do not cluster together into any meaningful aggregation. Also, sightline obstruction, which is not a lighting factor, intuitively clusters with tasks that involve person-to-person visual contact, and observation in the setting. Variables in each cluster were aggregated (using arithmetic average values of evaluation data) and renamed as new variables, with the first as 'near visual tasks' (NVT) and the second as 'far visual task' (FVT).

Results of principal component analysis of acoustical factors suggested similar clustering effects. Six dependent variables were related to courtroom functions in the auditory domain. Similar to the analysis involving visual tasks, the principal component analysis of the outcome variables in the auditory domains suggested two underlying aggregated dimensions/components, which is presented in Table 2. The two components, after Varimax rotation, explained 89.18% of total variance in the dependent/outcome variables. A closer study of the two components makes it obvious that the first four variables contribute mostly to the first component, and the last two variables to the second component. The two components also have intuitive appeal. The first component appears to be related more to speech clarity and audibility, while the second component deals more with speech privacy, two extremely critical functional requirements in courtrooms. Using aggregation technique similar to visual environment evaluation data, the first cluster of variables was named as 'conversation' (or speech comprehension; SCI), and the second cluster was named as 'privacy' (speech privacy; SPI).

A third class of dependent/ outcome variable cluster pertained to symbolic rendition of the courtroom setting. While this functional requirement has little to do with traditional areas of inquiry in building science and physics, the environmental parameters that influence the symbolic rendition of courtrooms includes domains from the latter. For instance, both lighting (structured illuminance levels) and acoustics (reverberation time) has been used through the ages in symbolic rendition of religious buildings and other settings of symbolic importance to the community. There were only two outcome variables in the study (although more can be added in fu-

**Table 2.** Outcome of Principal Component Analysis showing rotated component matrix of variables related to auditory tasks.

| **Outcome measures** | **Brief explanation of measurement** | **Component** | |
|---|---|---|---|
| | | **1** | **2** |
| Loudness-well | Speech of people within the Well area; examining deposition evidence; listening to video presentation | .892 | .276 |
| Clarity-well | Understanding speech in Well; deposition evidence; video presentation | .899 | .282 |
| Loudness-gallery | When people in the Gallery speak; e.g. during jury selection | .941 | .153 |
| Clarity-gall | Ability to clearly understand speech from the Gallery | .925 | .155 |
| Privacy others | Overhearing other's private discussion/conference | .321 | .888 |
| Privacy self | That others cannot hear you when you are discussing/conferring | .123 | .947 |

future studies) that focused on courtroom symbolism. One referred to the lighting, and the other to courtroom geometrical properties. A correlation analysis sufficed, instead of a principal component analysis. The analysis suggested that the two variables are highly correlated (Pearson Correlation = 0.639, significant at 0.01 level). Following a step similar to the ones adopted for visual and auditory tasks, the two variables were combined into a single measure named 'symbol' (courtroom symbolism; CSI).

A final class of dependent/ outcome variables have little similarity with the domains typically addressed in building science and physics – that of the dimensional attributes (length, area, seating capacity, etc) of courtroom spaces and elements, and will not be discussed in detail. A brief overview, however, is warranted to provide a holistic perspective of the modeling effort conducted in this study. Seven outcome variables pertaining to the degree of supportiveness of courtroom dimensional attributes to various phases of trial proceedings were included in the principal component analysis. The variables included size and shape of courtroom well, seating capacity in the gallery, area and seating capacity in the public waiting area, and work surface area and storage capacity in the various workstations (judge's bench, reporter, deputy/ clerk, attorney and security). The results of the principal component analysis suggested three clusters. The first component contributed more to the well size, well shape, and gallery capacity–courtroom variables. The second component contributed more to public waiting size and public waiting capacity. Finally, the third component contributed more to workstation size and storage area. The three dimensions, combined, explained 86.56% of total variance in the outcome variables. The three aggregated clusters of outcome variables were named as 'courtroom physical support' (CPI), 'public physical support' (PPI) and 'workstation physical support' (WPI).

The three aggregated clusters were added to the previous five mentioned above to create eight aggregated clusters of performance dimensions that have intuitive appeal to courtroom stakeholders. As mentioned previously, requirements related to courtroom security were excluded from the study owing to logistics, especially in a post 9-11 scenario. Inclusion of security dimensions may lead to more number of aggregated clusters of outcome measures. Further, several of the outcome measures collected during the study were not included in the analysis. Among others, outcome measures pertaining to supportiveness of the thermal environment were excludeed since a preliminary analysis of actual thermal measurements did not demonstrate considerable variability across courtrooms.

The aggregated clusters of outcome measures (courtroom performance dimensions) were subsequently modeled using linear and hierarchical multivariate regressions models. To maintain emphasis on the articulation of the modeling effort, the linear multivariate models are elaborated in the next section. Issues pertaining to other classes of models are discussed in the concluding sections.

## MODELING RELATIVE INFLUENCE OF ENVIRONMENTAL AND SOCIO-CULTURAL FACTORS

The primary essence in the modeling approach was to include all hypothesized factors within a model that could influence one or more of the outcome measures in an aggregated cluster. Using statistical modeling approaches presents an added advantage. Unlike algebraic and differential equations used in traditional normative models, the statistical models bear the capability to include data at interval, ordinal as well as categorical levels of measurements. Thus, soft data pertaining to personal and cultural factors are amenable to the modeling process, along with hard data. The predictor variables, thus, included not only environmental factors but also dimensional and socio-cultural attributes. Based on existing hypotheses in the field of building science/ physics, and in Environment Behavior studies eight multivariate models were developed. The predictor variables for each aggregated cluster are listed in Table 3, excludeing user attributes that were more or less uniform in all models.

The derived models are shown in equations 1 through 8 below. Each model was derived by regressing the hypothesized physical and environmental variables (objective measures), and user attributes (categorical and objective measures) over aggregated task performance indicators (such as Near Visual Task). Attributes in the model measured at the categorical level were measured in relation to one reference group. For instance, 'judge' was used as the reference group in comparison to which other 'role' types were measured. Similarly, 'male' was used as the reference in 'gender'.

### NVT (near visual task)

NVT = 6.87 + 0.004 (*task illuminance*) + 0.03 (*task:background luminance*) – 0.017 (*task:surrounding luminance*) + 0.045 (*background:surrounding luminance*) + 0.005 (*max_task*) + 0.001 (*window area*) + 0.04 (*work surface length*) + 0.85 (*work surface depth*) – 0.039 (*age*) -0.546 (*gender*) – 0.231 (*years of occupation*) – 0.332 (*deputy*) – 0.552 (*reporter*) – 1.34 (*attorney*) + 0.888 (*security*) (1)

### FVT (far visual task)

FVT = 5.768 – 0.227 (*horizontal:vertical illuminance - well*) + 0.088 (*horizontal : vertical illuminance - gallery*) + 0.058 (*surrounding : ceiling luminance*) – 0.014 (*age*) + 0.000 (*years of occupation*) - 0.000 (*courtroom area*) – 0.007 (*% sightline obstructed*) – 0.32 (*deputy*) – 0.398 (*reporter*) + 0.084 (*attorney*) + 0.442 (*security*) (2)

### SCI (speech comprehension)

SCI = 10.107 – 1.077 (*reverberation time*) – 0.079 (*background noise*) – 0.049 (*% sightline obstructed*) – 0.101 (*years of occupation*) – 0.016 (*age*) – 0.136 (*gender*) – 0.76 (*deputy*) – 1.342 (*reporter*) + 0.279 (*attorney*) + 0.3 (*security*) (3)

### SPI (speech privacy)

SPI = 7.283 + 1.004 (*reverberation time*) – 0.097 (*background noise*) – 0.186 (*years of occupation*) – 0.006 (*age*) – 0.374 (*gender*) + 0.649 (*deputy*) + 0.335 (*reporter*) – 0.33 (*attorney*) + 1.12 (*security*) (4)

### CPI (courtroom physical support)

CPI = 0.175 + 0.053 (*well length*) +0.098 (*well width*) + 4.855 (*well shape*) + 0.008 (*gallery capacity*) –0.083 (*years of occupation*) – 0.001 (*age*) – 0.595 (*gender*) – 0.54 (*deputy*) – 0.301 (*reporter*) – 1.808 (*attorney*) (5)

### PPI (public physical support)

PPI = 5.532 + 0.006 (*public waiting area*) – 0.008 (*public waiting capacity*) – 0.224 (*years of occupation*) + 0.132 (*deputy*) – 0.802 (*reporter*) – 1.703 (*attorney*) + 0.657 (*security*) (6)

### WPI (workstation physical support)

WPI = 5.689 + 0.045 (*work surface length*) – 0.173 (*work surface depth*) + 0.028 (*work station storage*) – 0.045 (*years of occupation*) – 0.005 (*age*) – 0.309 (*gender*) – 0.583 (*deputy*) – 0.287 (*reporter*) – 1.407 (*attorney*) – 0.624 (*security*) (7)

### CSI (courtroom symbolism)

CSI = 7.306 – 1.798 (*courtroom shape*) + 0.987 (*courtroom physical*) + 0.115 (*bench physical*) +0.008 (*jury physical*) – 0.011 (*gallery capacity*) + 0.423 (*horizontal: vertical illuminance – well*) + 0.183 (*horizontal : vertical illuminance–gallery*) - 0.016 (*surrounding : ceiling luminance*) + 0.117 (*surrounding : floor luminance*) (8)

## DISCUSSIONS

The predicted (dependent) variable in each model, in equations 1-8, constitutes one of the aggregated outcome measures listed in Table 3. These classes of models are 'n-dimensional', since every predictor (independent) variable adds a dimension. Parameter (slope) estimates associated with the independent variables measured at interval/ratio level (continuous variables) represent the predicted change in the dependent variable (outcome measures) for one unit change in the predictor variable, everything else remaining equal. Parameter estimates of independent variables measured at the categorical/ nominal level represent the predicted difference in outcome measure for a particular subcategory (in role, age, sex) from the reference group selected for that sub-category (for instance, between judges and reporters), everything else remaining equal.

Some salient features of the integrated models include: 1) the models integrate variables from multiple domains, 2) they focus on a smaller set of meaningful aggregated functional dimensions intuitive to stakeholders of a setting, 3) they are context specific, and 4) they capture instrumental as well as abstract functions, such as courtroom symbolism. It needs to be underscored that these models are courtroom specific, and cannot be used in other setting types.

A pertinent question is how this class of models supplements the traditional modeling paradigm in building physics? Four areas of possibilities warrant elaboration. First,

**Table 3:** Predictor variables (environmental and physical) associated with aggregated outcome measures.

| Aggregated cluster | Interpretation | Predictor Variables |
|---|---|---|
| NVT: Near visual task | How well is the courtroom environment predicted to support visual (desktop) tasks? | Task/work illuminance, task: background luminance, task: surrounding luminance, background: surrounding luminance, window area, work surface length, work surface depth, years of occupation. |
| FVT: Far visual task | How well is the courtroom environment predicted to support visual tasks across the courtroom? | Horizontal:vertical illuminance (well), horizontal:vertical illuminance (gallery), surrounding:ceiling luminance, courtroom area, % of sightline obstructed, years of occupation. |
| SCI: Speech comprehension | How well is the courtroom environment predicted to support speech comprehension? | Reverberation time, NC rating, % of sightline obstructed, years of occupation. |
| SPI: Speech Privacy | How well is the courtroom environment predicted to afford speech privacy? | Reverberation time, NC rating, years of occupation. |
| CPI: Courtroom physical support | How well is the courtroom's physical attribute predicted to support functions conducted within it? | Well length, well width, well shape, gallery capacity, years of occupation. |
| PPI: Public physical support | How well is the public waiting area's physical attributes predicted to support functions conducted within the courtroom? | Public waiting area, public waiting capacity, years of occupation. |
| WPI: Workstation physical support | How well is the physical attribute of courtroom elements predicted to support functions conducted within the courtroom? | Work surface length, work surface depth, workstation storage capacity, years of occupation. |
| CSI: Courtroom symbolism | How well is the courtroom environment predicted to portray appropriate symbolic values? | Courtroom shape, standardized aggregation of (courtroom area, courtroom height, window area), standardized aggregation of bench elevation, bench edge-lip height), standardized aggregation of (jury first row elevation, number of jury tiers), gallery seating capacity, horizontal:vertical illuminance (well), horizontal:vertical illuminance (gallery), surrounding:ceiling luminance, surrounding:floor luminance. |

the models capture the relative influence of predictor variables on the aggregated performance measures. Standardized parameter estimates, which are simultaneously derived with the parameter estimates reported above, provide a quick way of reviewing relative influences. For instance, traditional lighting models do not elaborate precisely the relative influence of illuminance, the various aspects of the luminous environment and glare factors on tasks. An understanding of the relative influence provides an easier way for building stake-holders to identify greater influential factors while procuring and managing facilities. For instance, in court-room settings, task to background luminance ratio proves to be the most influential of all lighting variables.

A second factor pertains to the statistical significance of the predictor variables. Predictor variables resulting in non-significant parameter estimate suggest that despite standard assumptions in generic models, in a particular setting (courtrooms in this case) a particular environmental variable could be inconsequential in its influence on a function. For instance, work surface illuminance resulted in a non-significant parameter estimate in near visual tasks, indicating that within the range of prevailing illuminance in courtrooms, it may not constitute an influential variable. Similarly, the ratio of horizontal to vertical illuminance had a parameter estimate with a higher significance value as well as larger relative influence as compared to other lighting parameters in far visual tasks. This is intuitive, since larger values of the ratio results in more prominent shadows on the faces of the witnesses, jurors and others, which impedes the task of facial observation–an extremely important courtroom task. These results also offer the promise of validating assumptions built into traditional models in building physics in actual settings, such as the one involving law of diminishing returns related to illuminance. Following the same approach with POE data from other setting types, traditional models can be validated across setting types.

A major strength in this approach is in the inclusion of user attributes. Including personal variables, for instance role, age or gender, increases the sensitiveness of the models. The models could be targeted separately for different stakeholders-judges, deputies, reporters, attorneys, security, etc. That would enable prediction of performance from the viewpoint of important stakeholder groups. From a policy perspective, it remains the task of the stakeholder groups to decide whether to optimize predictions for one or more user attributes. Alternately, the models could be developed without user attributes, which will essentially average out the predicted outcome measures across personal/ cultural variations.

Finally, from an end-user perspective, collapsing a large number of outcome variables into a few intuitively meaningful aggregated performance dimensions provides a different avenue for utilization of building physics models. For courtroom stake-holders, aggregated dimensions bear greater meaning as compared to lower level parameters such as illuminance or reverberation time. Across work settings aggregated constructs such as learning, collaboration, innovation and productivity are gaining importance among stakeholders. The modeling approach described here offers one modality for linking building physics constructs with higher-level objectives. This study focused on the supportiveness of courtroom settings to trial proceedings.

Follow-up study could improve upon several areas. First, this study focused on linear and hierarchical multivariate models. Hierarchical multivariate models (or multilevel models) are better suited in case of clustered data such as the ones collected in this study where users are clustered within courtrooms. It could be argued that the outcome measures are influenced by variables/ attributes at the lower level (individual level attributes) as well as the upper level (courtroom attributes). In other words, the variance of the outcomes could be attributed to both levels of independent variables. In such circumstances theory suggests (Hox, 2004) the possibility of violation of the assumptions of data independence in OLS (Ordinary Least Square) analyses. Further, using OLS regression for clustered data sets involves yet another problem. In truly clustered data sets, the sam-pling variance of the estimated parameters is large when fitted into OLS models. In such cases, insignificant find-ings could show up as significant, spuriously, although the parameter estimates remain unbiased. Hierarchical models were developed and tested for the linear (OLS) models described in this paper. Evidences of spurious associations were not forthcoming. Although hierarchical models are better suited to clustered data, there are some advantages associated with linear modeling. Linear models are considerably simpler to comprehend and interpret, especially when the audience includes people unaccustomed to mathematical/ statistical procedures, such as stakeholders in a building project. In basic research, hierarchical modeling consti-tutes the more appropriate approach. In work geared towards practical applications, hierarchical models serve to check for violations of OLS assumptions, and linear models offer the best in comprehensibility.

Non-linear models offer yet another avenue to explore possibilities of better fit. The use of logit and probit models (Aldrich and Nelson, 1984) has been attempted in building physics in the past (Auliciems, 1989) in the domain of thermal comfort. They developed a prediction model that captured the combined influence of several environmental parameters on thermal comfort level. Logit and probit models (or Probablity Models) overcome one problem in modeling involving ordinal level outcome measures. Scales using 1-5, 1-7 or 1-10 for recording outcomes are typical to most POE studies. In such cases, predictions using linear regression models can, theoretically, result in projected outcomes that lay outside the end-points of the scale used for measurements. By limiting any possible outcome projection to the scale end-points, probability models help improve meaningfulness of POE data models. However, once again, interpreting probability models is simplest in case of dichotomous outcome variables. These and other modeling options could be tried out in future comparative studies to assess degrees of accuracy and comprehensibility. Such discussions constitute the topic of a separate paper. The modeling effort presented here, nevertheless, constitutes a novel approach towards bridging stakeholder needs in specific contexts and building physics research.

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