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Occupant satisfaction as an indicator for the socio-cultural dimension of sustainable office buildings – Development of an overall building index

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Abstract

Driven by policy guidelines and interest of the real estate market, building performance evaluation is becoming a growing marketing factor. While methods and strategies for the monitoring of technical or economical characteristics are widely established, little is known about approved criteria for the socio-cultural dimension of buildings. Particularly there is a lack of time- and cost-effective procedures with regard to evaluation of comfort at workplaces. Based on surveys in office buildings an overall building index has been developed which is presented in this paper. Computations were done by Correspondence Analysis and Principal Component Analysis (PCA) with optimal scaling which both proved evidence for an overall building index based on simply summed mean scores derived from relevant comfort parameters. Beyond the index a praxis-oriented tool for the real estate market has been developed which provides information on the outcome of each parameter for supporting day-to-day operations in new (sustainable) and existing buildings.

Keywords: overall building index, occupant satisfaction, sustainability, certification systems, energy saving.

1 Introduction

Offices represent an important work environment and are a worthwhile challenge in the context of designing sustainable buildings with low energy consumption, which provide comfort for the employees as well. Beside the use of renewable energy and environmentally friendly building materials, planning sustainable 'Office Buildings for the Future' (Voss, Löhnert, Herkel, Wagner & Wambsganß, 2006) should consider low energy demand for heating, cooling, ventilation and lighting while meeting the needs of the occupants at the same time.

Thus, driven by new policy guidelines and rising interest of the real estate market, building performance evaluation is becoming a crucial issue. Post-occupancy evaluation (POE) is a diagnostic tool and system which allows facility managers to identify and evaluate critical aspects of building performance systematically based on the employees' day-to-day experiences (Preiser, Rabinowitz & White, 1988). In the conceptual framework for Building Performance Evaluation (BPE) of Preiser and Schramm (2005) the process model involves POE as an important loop to get feedback from the occupants. POEs can be applied to identify problem areas in existing buildings and to evaluate new building prototypes as well: `POEs also test some of the hypotheses behind key decisions made in programming and design phases´ (Preiser & Schramm, 2005, p. 19). This is especially of interest for new sustainable buildings evaluated in certification processes.

Certification systems and labels are auxiliary instruments for the practical application of political objectives and concepts in the building industry, e.g. `The Concerted Action supporting transposition and implementation of Directive 2002/91/EC of the European Parliament and of the Council (CA EPBD)´. Moreover they are supportive to fostering sociopolitical and professional discussions (Kaufmann-Hayoz et al. 2001). On a general level they contribute to a more holistic strategy in the handling of existing building stocks.

A variety of rating systems like BREEAM (Building Research Establishment's Environmental Assessment Method, UK) or LEED® (‚Leadership in Energy and Environmental Design', U.S.) have been established and are updated continuously. In Europe the development and implementation of national certificates is an increasing issue. In Germany, a voluntary certification system for office and administration buildings has recently been launched. A short overview is given below.

The German Certification for Sustainable Office and Administration Buildings

The Federal Ministry of Transport, Building and Urban Affairs (BMVBS) in cooperation with the German Sustainability Buildings Society (DGNB) developed a voluntary certification system for sustainable new office and administration buildings: It is understood as a quality assurance system for the building industry as well as the society. It was developed by scientists and experts of the construction and real estate sector on the basis of `the complete value chain of the construction (…) and gives a clear orientation for this future-oriented economical sector. (…) The certificate is based on the concept of integral planning, defining at an early stage, the aims of sustainable construction´ (www.dgnb.de). As an achievement-oriented rating system, it comprises all relevant topics of sustainable buildings: quality of ecology, economy, techniques, functionality and processes as well as the socio-cultural dimension. This topic includes comfort parameters like thermal, visual and aural comfort, air quality and options for occupants' control (e.g. operable windows) as well as safety and security aspects. Like for most European countries (Maldonado, Wouters & Aleksander Panek, 2008), the certification is predominantly based on standards and calculated data. Auditors evaluate a building by a matrix and supporting software with respect to the maximum number that can be achieved for the subsets of the main topics. The calculated results are transformed into a degree of compliance, given in percentages, for example `thermal comfort´ is assured to 100%, `visual comfort´ to 80% and so forth. The mean percentages for the main topics such as the `socio-cultural dimension´ are calculated and transformed into a German school mark to make the results more comprehensible. Outstanding new buildings are awarded depending on the degree of compliance, with certificates and plaques in the categories gold (80%), silver (65-79,9%), or bronze (50-64,9%). Additionally, planned buildings can get a pre-certificate allowing owners to optimise their building and to market it at an early stage with verifiable statements about its sustainability.

Currently the certification system is expanded to existing buildings. Concerning the socio-cultural dimension, it is intended to implement occupant surveys. Credit points can be obtained by conducting surveys within a continuous monitoring procedure. In this paper we present the development of a method for the real estate market with focus on comfort at workplaces fitting to the criteria of the socio-cultural dimension of the German Certification system and therefore suitable being incorporated into the certification procedure for existing buildings. It is based on POE field studies of the authors.

2 Project background and objectives

While methods and strategies for the evaluation of the technical or economical performance of a building are widely established, little is known about approved criteria for the socio-cultural dimension when it comes to building performance evaluation. What does `socio-cultural´ mean? On a general level, `socio-cultural´ is an umbrella term for a variety of cultural, social or political interests and needs of a society or social group. Combining the aspects `social´ and `cultural´ represents their strong relation with respect to social groups and their value systems. Furthermore it is a term of cultural and educational policy and stands for the responsible actors' turning towards social reality and everyday life. Thus, in the field of building industry involving the occupants' day-to-day experiences with a building would be a symbol for participation and would meet the idea of turning towards social reality. Although occupant surveys are seldom part of rating systems so far information from the occupants' perspective would benefit quality management, could help to prevent vacancies in buildings and support consultation as well as negotiations in transaction processes. As complement to technical monitoring or lifecycle analyses, surveys have a great potential of gaining relevant feedback from the occupants as a basis for various improvements in energy efficiency regarding day-to-day operations. Experiences show that there is often a gap between the calculated and the metered energy consumption for a variety of reasons which can be assessed by continuous monitoring. Similarly, the occupants' votes also allow a continuous check whether forecasted comfort parameters can be achieved in real building operation. Currently there is a lack of time- and cost-effective procedures with regard to evaluation of comfort at workplaces when the aim is to have a quick overview about the building performance based on occupants' votes.

Main goal of this project was (1) the development of an overall building index and (2) the development of a manageable (time- and cost-saving) and praxis-oriented instrument with focus on occupant satisfaction.

(1) According to theoretical or empirical findings indices can be developed by adding or multiplying scores either with or without weighting factors. Our literature review did not reveal any clear ranking for comfort parameters and therefore necessitating a

special weighting. In the history of statistics differential weighting was already a matter of discussions. Spearman, Thurstone or Likert dealed with this issue and the following questions: `…How to define the univariate scale? Can it be by simply adding scores or by some sophisticated differential weighting method?´ (Gifi, 1990; p. 83). Empirical studies for differential weighting showed little effects, especially when variables are highly correlated. Guilford concluded: `…weighting is not worth the trouble…´ (1936, qtd. in Gifi, 1990, S. 83) and Wainer (1976, Ibid.): `Estimating coefficients in linear models: it don't make no never mind´.

Thus, the concern in this project was to test if there was evidence to keep it simple and to develop an overall building index based on an indicator subset from the applied questionnaire which covers relevant comfort parameters.

(2) The instrument should include an easy to handle computer-based instrument for the Facility Management Staff which is applicable in the real estate market when it comes to benchmarking and day-to-day operations in non-residential buildings. The purpose was to support decision making for improvements in the building concerning comfort and sustainability. The occupants' votes should be indicated on different information levels. Besides a more detailed building signature by means of mean scores and frequencies of categories concerning relevant comfort issues (e.g. temperature, lighting) a combined overall building index would allow the ranking of single buildings in comparison to a building stock on an aggregated level.

3 Method

3.1 Data and material

The study is based on field studies on workplace quality which have been performed with focus on energy efficient buildings (Wagner, Gossauer, Moosmann, Gropp & Leonhart, 2007). The applied questionnaire was developed in accordance to frameworks from environmental psychology (Bechtel, 1997; Brill, Margulis, Konar and BOSTI, 1984; Gifford, 2002; Sundstrom & Sundstrom, 1986), findings in the field of the sick-buildings-syndrome (Bischof, Bullinger-Naber, Kruppa, Müller & Schwab, 2003) and the questionnaire of the Center for the Built Environment, University of California, Berkeley (www.cbe.berkeley.edu). With regard to the development of an overall building index, the range of assessed buildings has been

expanded in 2008 and 2009 to different building types, mostly to old or refurbished buildings, to get a more profound basis for the statistical methods. Only buildings with more than 30 participants in the survey were included in the analyses. Occupants in the assessed buildings were employees from civil service and the private sector. The response rate averaged 79% of the manually distributed questionnaires.
The questionnaire was slightly modified in 2008 by systematising the indicator subsets for comfort parameters and the accordant questions `Overall, how satisfied are you with … at your workplace?´ (Table 1). Beyond questions concerning the workplace, items were added which broach the issue of the entire building (e.g. restrooms, conference rooms) and which coincide with the criteria for the German certificate (e.g. safety, security).

Two approaches were chosen to prove if there is statistical evidence for an overall building index: (a) Correspondence Analysis, a method often used in social research or market research and (b) Principal Component Analysis (PCA) with optimal scaling. Both methods have very flexible requirements for the data and can be applied as exploratory methods for representing multivariate datasets. The aim was to prove if large sets of variables could be reduced to few dimensions by aggregating individual-level data to construct measures for units at a higher level.

3.2 Correspondence Analysis

Correspondence Analysis is a method of factoring multiple categorical variables and displaying them in a property space which provides a global view of the data useful for interpretation (Benzécri, 1992; Cibois, 2007; Greenacre, 1993). Variables can be considered simultaneously. The primary goal is a graphical display of contingency tables, i.e. rows and columns. The association of the variables is visualised on a correspondence map in two or more dimensions. Eigenvalues reflect the relative importance of the dimensions. The first dimension always explains the highest inertia (variance) and has the largest eigenvalue, the next the second-highest, and so on. Points (variables) are plotted along the computed factor axes, i.e. dimensions (Figure 1). The map can help detecting structural relationships among the variable categories. In contrast to the Chi-square test which shows if there is a relationship, the correspondence analysis shows the character of the relationship between variables.

Very similar objects (variables) are very close to each other, unlikely objects are distant from each other. To give an example for the used questionnaire in which a five-point-Likert scale (coded 1 to 5) was applied: When the correlation between two comfort parameters is high, the `1s´ should be grouped together, the `2s´, the `3s´ and so forth. The `1s´ and the `5s´ should be distant from another in the graphical display.
The applied software was Trideux (French free software: http://pagesperso-orange.fr/cibois/Trideux.html), however correspondence analysis is supported by other software as well (e.g. SPSS, SAS).

3.3 Principal Component Analysis (PCA) with optimal scaling

PCA is mostly used as an instrument in exploratory data analyses and for making predictive models. PCA is the simplest of the true eigenvalue-based multivariate analyses. Its operation can be thought of as revealing the internal structure of the data in a way which best explains the variance in the data. Once again, as with the correspondence analysis, the aim is to reduce a set of variables to a set of underlying superordinate dimensions.
The basic idea of optimal scaling is to transform the observed variables (categories) in terms of quantifications for further computations. Ordinal values from the Likert-scale (very dissatisfied = 1 to very satisfied = 5) are transformed into metric values which can be used for further computations. PCA involves the calculation of the eigenvalue decomposition of a data covariance matrix. Results are usually discussed in terms of component scores and loadings. Analyses were carried out by applying PASW Statistics (Predictive Analytics Software, formerly SPSS).

4 Results

4.1 Correspondence Analysis

The biplot in Figure 1 shows one dimension which can be considered as a scale for general satisfaction, the score for the eigenvalue (λ) is sufficient to consider dimension 1 as a valid scale. Thus, the data are suitable for aggregation.
The distribution of the grouped and framed variables represents the characteristic of the ordinal character i.e. the profile of the variables: they are plotted along the principal axes (dimension 1). As shown in the Figure, the comfort parameters are

predominantly grouped together according to their values from 1 (very dissatisfied) over 3 (neutral) to 5 (very satisfied). This represents the high correlation between the variables: high satisfaction (e.g. coded by 5) with one comfort parameter appears with high satisfaction with the other comfort parameters, this is the same for variables coded by 4, 3, 2 and 1.

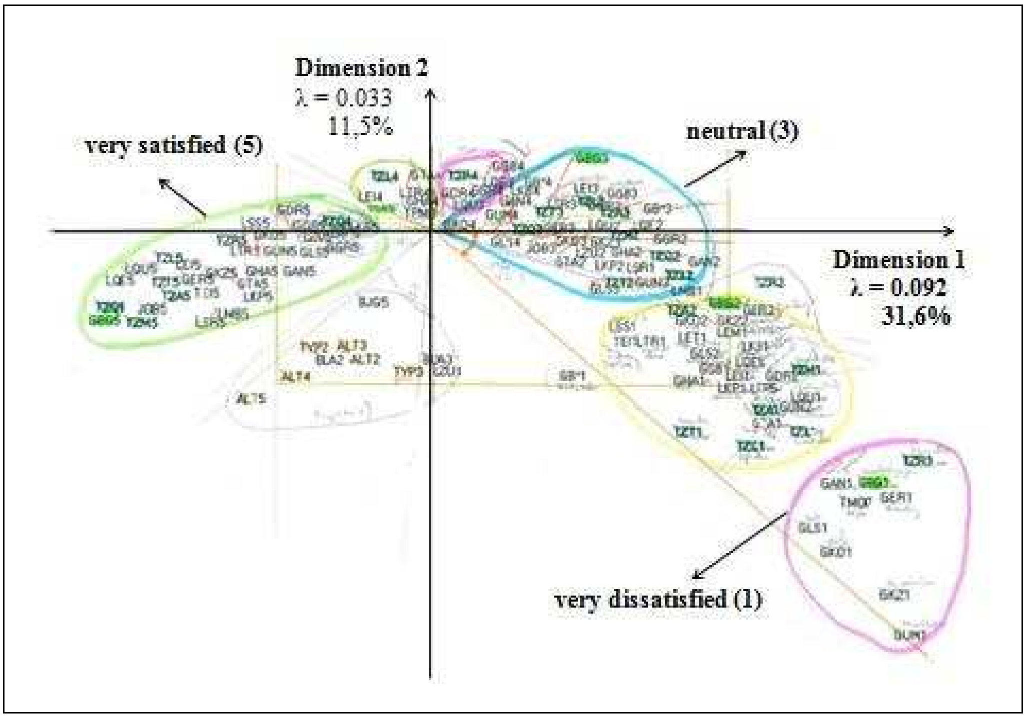

Figure 1 Output for the Correspondence Analysis with Trideux after interpreting and marking of relevant outcomes.

(Eigenvalue $\lambda > 0,1$ = strong correlation between variables, λ 0,01 - 0,1 = standard, $\lambda <$ 0,01 = weak correlation, could be at random, Cibois, 2007). Sample: 23 buildings, N = 1,329. 69 variables were chosen concerning satisfaction with comfort parameters at the workplace, including `Overall…´-questions.

The `horseshoe´- or `Guttman´-effect in the graph might arouse interest, but with regard to content there is no interesting information for interpretation in it. The arch is a methodical effect due to the geometric character of the correspondence analysis. Primarily the underlying relationship for the relevant dimension 1 is a linear one.

4.2 Principal Component Analysis (PCA) with optimal scaling

Table 1 shows the variables which cover overall satisfaction for comfort parameters concerning workplace. The related subsets to the questions are given as complementary information on the different aspects rated by the occupants.

Table 1 Overall´ comfort variables and related subsets

Summarising `Overall…´- questions	Indicator subsets
Overall, how satisfied are you with **temperature** at your workplace?	e.g. sensation of temperature, preference of temperature, control
Overall, how satisfied are you with **air quality** at your workplace?	e.g. humidity, odour, control
Overall, how satisfied are you with **light conditions** at your workplace	e.g. daylight, artificial light, blinds/shades, control
Overall, how satisfied are you with **acoustics/noise** at your workplace?	e.g. noise coming from technical equipment, colleagues
Overall, how satisfied are you with **spatial conditions** at your workplace?	e.g. privacy, individualization of the workplace
Overall, how satisfied are you with **furniture/layout** at your workplace?	e.g. desk, chair, materials and colors of walls and ground)

After having tested that reliability for the indicator subsets is given (average r = .79), all six summarising `Overall…´-questions concerning comfort parameters at the workplace were comprised in the analysis to test for the underlying dimensions in the data.

Table 2 shows that all variables load well on the first dimension (eigenvalue 3,316), and can be considered as a scale for general satisfaction with the workplace. High scores mean a high level of satisfaction: people who are satisfied with one comfort parameter are also satisfied with the others. Dimension 2 has no importance (eigenvalue 0,949), because dimensions with eigenvalues smaller 1 have less weight than the original single variables themselves. Nevertheless dimension 2 is quite interesting, because it shows both positive and negative scores and seems to represent a kind of polarisation by means of indoor climate conditions versus spatial conditions, furniture/layout and acoustics. Possibly further analyses by means of building characteristics may reveal an explanation for this finding.

Table 2 Component loadings for comfort parameters

Comfort parameter	**Dimension 1**	**Dimension 2**
Overall, how satisfied are you with **acoustics/noise** at your workplace?	,747	-,344
Overall, how satisfied are you with **spatial conditions** at your workplace?	,670	-,381
Overall, how satisfied are you with **furniture/layout** of your workplace?	,713	-,423
Overall, how satisfied are you with **lighting conditions** at your workplace?	,728	,049
Overall, how satisfied are you with **temperature** at your workplace?	,784	,560
Overall, how satisfied are you with **air quality** at your workplace?	,810	,427

Component loadings: > 0, 7 = very high, 0, 5 - 0, 69 high, 0, 3-0, 49 poor, < 0, 3 very poor (Hatzinger & Nagel, 2009). Sample: 14 buildings, N = 867; those buildings were chosen where the modified latest questionnaire with this set of 6 indicators for satisfaction at the workplace was applied.

Additionally, it was tested if differently computed `Comfort´ Scales including the six comfort parameters would correlate (Table 3). Beside the new metric variable obtained with the object score for dimension 1 from the optimal scaling, a weighted `Comfort´ scale was computed, based on multiple regression-analysis with the six comfort parameters (`Overall…´ questions, Table 2) as predicting variables and the question `Overall, considering all aspects, how satisfied are you with your workplace conditions?´ as dependent variable. A third scale, (`Comfort´ Scale – summed-) was computed by simply summing the mean scores of the six comfort parameters.

Table 3 shows strong correlation for the `Comfort´ Scale based on simply summed mean score with the other two differently computed `Comfort´ Scales (regression-analysis and optimal scaling). All three scores for the differently computed `Comfort´ Scale are highly correlated as well.

Table 3 Correlation Coefficients for different \`Comfort´ Scales

		\`Comfort´ Scale **-summed-**[1]	\`Comfort´ Scale **-weighted-**[2]	\`Comfort´ Scale **-object score for dimension 1-**[3]
\`Comfort´ Scale **-summed-**	**r**	1	,965**	,975**
	p		,000	,000
	N	867	867	867
\`Comfort´ Scale **-weighted-**	**r**	,965**	1	,940**
	p	,000		,000
	N	867	867	867
\`Comfort´ Scale -**object score for dimension 1-**	**r**	,975**	,940**	1
	p	,000	,000	
	N	867	867	867

[1] = sum of simply added mean scores for satisfaction with single comfort parameters,
[2] = standardised prediction value from regression analysis,
[3] = standardised prediction value for dimension 1 from optimal scaling.

Concluding, a scale for \`workplace satisfaction´ based on simply summed mean scores can be considered as valid for these data.

4.3 Final building index

Beyond occupants' ratings concerning their workplace the experiences of the occupants with the entire building is of importance when it is intended to give a comprehensive overview by means of an index. The modified latest questionnaire covers items which affect this issue. Occupants rate a subset of items (e.g. maintenance, restrooms, conference rooms, zones for informal contacts, security) as wells as a summarizing question (\`Overall, how satisfied are you with the building in general?´, reliability for the 18 items Cronbach's $\alpha$ = .91). The mean score for the summarising question \`Overall, how satisfied are you with the building in general?´ was added as a further indicator to the final building index. Data of our field studies revealed that occupants spent nearly 90% of their time in the office and only 10% in other areas of the building, thus the six comfort parameters for \`workplace satisfaction´ build the main part of the \`overall building index´.

The scale reliability (six indicators for satisfaction with workplace conditions and the added indicator for the overall satisfaction with the building) of this final index was tested, showing Cronbach's α = .82. Additionally, an explorative factor-analysis was carried out testing if the precondition for the Principal Component Analysis (PCA) with optimal scaling for the final \`overall building index´ is given. The assumption in

factor-analysis is that single indicators are highly correlated. A high value for the Kaiser-Meyer-Olkin-statistics (0,883) shows that homogeneity in the data is given.
The subsequent computations by PCA revealed a one-factor solution with high positive loadings for all seven indicators (> 0, 7) and an eigenvalue greater 1 (3, 856; residual eigenvalues < 1). Figure 2 illustrates the facets of the final `overall building index´.

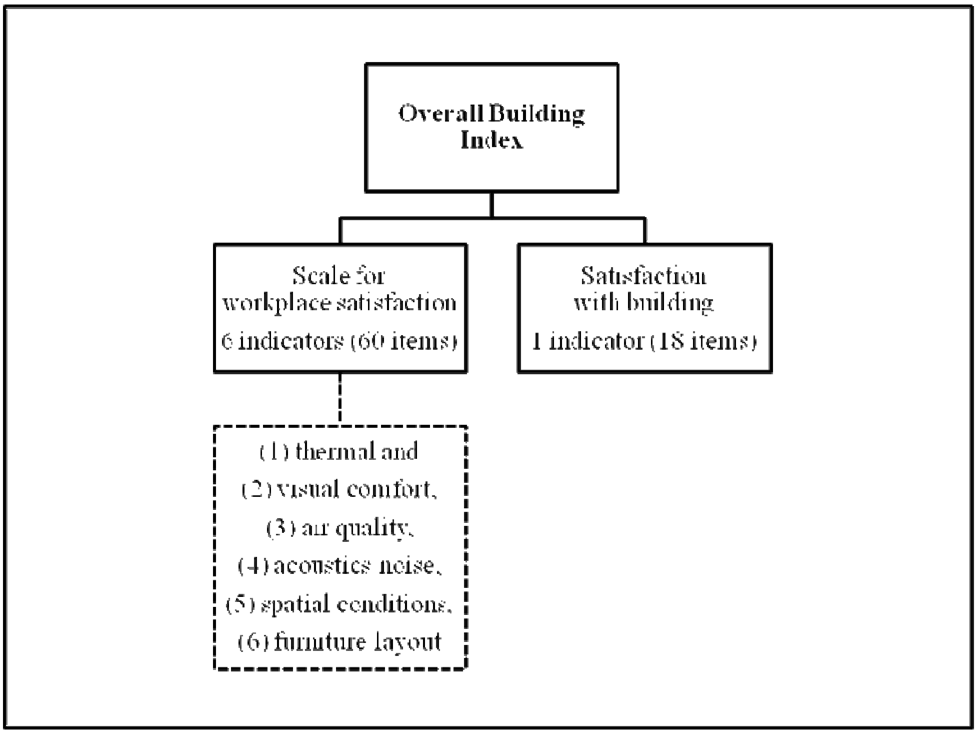

Figure 2 Facets of the final `overall building index´

4.4 Practical Implication

The application of the developed instrument in the context of post occupancy evaluation will be shown exemplarily by means of the latest sample held from field studies in the years 2008 to 2009.

(1) On a general level, the overall building index and the mean scores for comfort parameters serve as benchmarks with respect to a comparison of larger building stocks and to screen monitoring processes regarding occupants' feedback in single buildings (Figure 3).

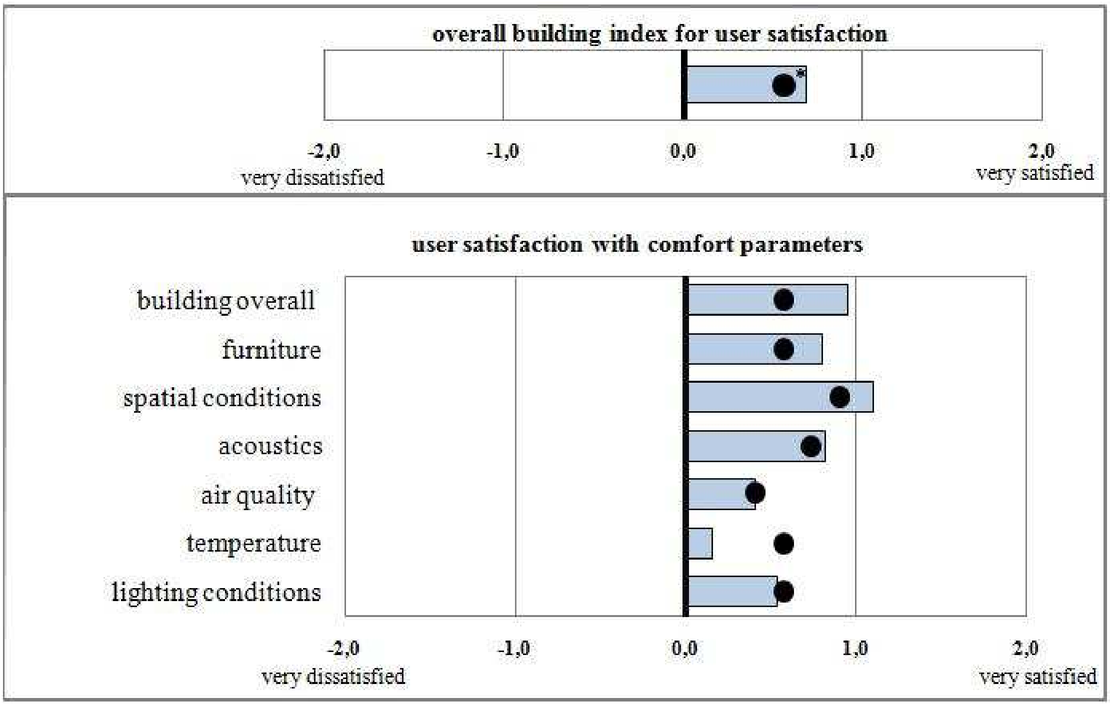

Figure 3 Results for a building with certificate in `gold´ in comparison to a sample of 15 buildings (*●, N = 915) assessed in winter 2008 and 2009.

The bars representing the outcome of the building with a certificate in `gold´ show that the building performs better than the sample representing the overall building index and a variety of comfort parameters (e.g. ratings for `building overall` and `spatial conditions´), but obviously the occupants experienced a problem with temperature. This information is helpful for the Facility Management staff planning interventions.

(2) The benefit of occupant surveys as part of the new German certification system for existing buildings is to compare the results to the predicted outcome for the socio-cultural dimension based on plans, standards and audits in a specific building and to detect the potential for optimisation. It is suggested to rate commissioned buildings regularly (fixed intervals of surveys) and with respect to the scope of topics (e.g. solely workplace, including building overall acceptance).

It has to be mentioned that the development of this instrument here and the development of the German certification system did not happen simultaneously; the first approach only started in the context of the above described project. For this reason a complete congruence is not possible: the summed up score for the socio-cultural and the functional dimension in the certificate includes a variety of management aspects, e.g. back-up options for the building control systems, which cannot be part of an occupant survey. Thus the overall building index and the score for the socio-cultural and functional dimension from the certification system cannot be compared directly. Moreover, the comfort parameters `spatial conditions´ and `furniture´ are not considered in the certification system, but they are highly relevant in occupant surveys in terms of overall satisfaction with a workplace. Nevertheless there is enough analogy to get hints for optimisation in a building by comparing the percentages of degree of compliance from the certification system and frequencies of satisfaction based on occupant surveys (Table 4).

Table 4 Ratings for a building with certificate in `gold´: predicted comfort from certification procedure (degree of compliance) and results from occupant surveys (N = 115) regarding comfort parameters ([1]survey in 2008, other comfort data are coming from survey in winter 2009)

Comfort parameters	**Predicted comfort** from certification system	**Experienced comfort** based on occupant survey	
		satisfied / very satisfied	dissatisfied / very dissatisfied
thermal comfort in winter	100%	43%	31%
thermal comfort in summer[1]	100%	45%	26%
air quality	100%	50%	16%
acoustics	100%	66%	6%
visual comfort	85%	73%	18%
user control**	67%	46%	26%

**includes air quality, temperature in winter and summer, daylight, artificial light, shades and blinds

Even if it is not realistic to obtain 100% satisfaction for comfort by subjective ratings, concerning the ambient environment conditions `temperature`, `air quality´ and `acoustics´ the outcome for this building shows an enormous gap between the predicted comfort and the results from the occupant surveys. Values for visual comfort are more congruent, may be due to the fact that in the certification procedure the architectural feature `atrium´ was taken into account which resulted in a reduced degree of compliance.

5 Discussion and conclusions

The aim of an index is to summarise information to a comprehensive, manageable and - where ever applicable - easy to communicate value. The simplest kind of an index is a summed score, e.g. held from items of a questionnaire. The question at hand in the presented project was if such a simply summed overall building index could be applicable regarding post-occupancy evaluation. For this purpose a statistical approach was chosen which (to our knowledge) is rarely used in this field. The applied Correspondence Analysis and Principle Component Analysis (PCA) are common explorative methods for reducing information in datasets and useful for ordinal data, which are typical for surveys regarding workplace environment. The results revealed that by means of both methods and complementary empiric-analytic methods like explorative factor-analysis and regression-analysis an overall building index could be developed. A factor resulted from the statistical procedures representing general satisfaction with comfort parameters at the workplace and with the building. This final `overall building index´ could be developed due to high correlations for the considered variables. Gifi (1990) broached this issue: `If all correlations in R [Burt Table, showing the frequencies for all combinations of categories of pairs of variables in a data set, K.S.-E.] are large, the correlation between any linear compound with nonnegative weights and the simple sum variate necessarily must be large, too´, (p. 83). The advantage of an index based on simply summed mean scores is that this value refers directly to the original ordinal scale level from the questionnaire, e.g. a five-point scale coded into `very satisfied´ (2) to `very dissatisfied´(-2). Results for the overall building index can be reported equally based on these codes and is thereby exceedingly comprehensible and doesn’t need any further transformation into threshold values.

The high attractiveness of an `overall building index´ obtained from surveys expresses itself by the possibility of a quick ranking of buildings in terms of occupant satisfaction. When it comes to portfolio analyses the index can be used as a basis in consultations, e.g. as a first orientation in the sense of a screening instrument for investors or owners. Thus, the challenge of the project goals was to balance praxis-oriented requests and scientific approaches. The results of the applied statistical procedures appear to indicate that a valid scale representing overall building satisfaction could be constructed. But is a single score adequate to represent the social reality concerning facets of comfort in a building properly?

The benefit of the statistical methods was discussed above; the final building index can be seen as a useful indicator regarding the socio-cultural dimension in buildings. But it has limitations as well. Buildings are complex due to e.g. architectural features, functionalities, and maintenance or occupant behaviour. Aside from quick evaluation, a responsible handling is required when problems in a building occur, and an overall index should not replace an in-depth evaluation in buildings to detect potential for optimisation. Based on an international dataset from 26 office buildings in five European countries, Humphreys (2005) analysed the accuracy of prediction for a combined index which ranked comfort parameters with regard to indoor environment. His conclusion was that an index failed because the weightings for the comfort parameters varied. We strongly agree to his recommendation: `It seems prudent, then, to continue to consider each aspect separately (…) rather than to rely solely on overall evaluation.´ (p. 325). Thus, beyond the `overall building index´ and with regard to the Facility Management staff we developed an instrument for surveys which includes a detailed feedback for each comfort parameter supporting day-to-day operations in a building.

Another limitation to the findings may be the sample size. The acquisition of buildings is often complicated and troublesome for a variety of reasons, e.g. time consuming decision procedures. Fears might be raised in the board of management for agitation among the employees initiated by a survey or in terms of cost-intensive improvements. Probably we ended up with a selective and too homogenous sample. On the other hand, the question is if significant differences in the outcome of building ratings are expectable due to relatively high standards for buildings and the indoor environment in Germany. When looking at the complexity of subjective perception, there is evidence from environmental psychology in the field of housing showing effects like the `satisfaction paradox´ or the `dissatisfaction paradox´ (Glatzer & Zapf, 1984): people are satisfied with their housing environment despite objectively uncomfortable conditions and vice versa. Additionally, a bias in perception may have an impact on occupants' satisfaction due to specific building types. In their analyses of `Green buildings´ Leaman and Bordass (2007) found the following tendency in occupants' ratings: `If they like the design, and their experience of using the building is generally good and supportive for their work tasks, even if there are chronic problems with it, users will tend to be more tolerant.´ (p. 671).

Comparisons among colleagues concerning the perception of indoor environment and comparisons between different offices in their working life are presumably affecting ratings of the functionality of a workplace or a building. But, the relationship between occupants and the building cannot be reduced to functionality: `…occupants do not assess their functional comfort on the basis of simple physical comfort. They bring feelings, memories, expectations, and preferences into their assessment, and this increases the complexity of the outcomes being measured (Veitch, 2008, p. 236). Furthermore, when considering comfort as `a matter of culture and convention´ (Chappells & Shove, 2005, p. 33), changes in importance of comfort parameters over time respectively generations are expectable, and so instruments for measuring subjective issues should be well defined and adjusted for its scope. The discussed aspects illustrate the complexity of the social issues in the field of building performance and the challenge of translating social reality into scores.

The database for occupant surveys in Germany is still too small to define threshold values or standards for the socio-cultural dimension (presuming this is basically a realistic approach), this would demand a standardised sample. Nevertheless a continuous assessment of occupants' feedback seems to be a useful part for evaluating the sustainability of buildings in certification systems. With respect to energy efficiency and optimal building operation a great potential can be seen in occupants' behaviour. In the sense of Gibson's' theory of ecological perception feedback-systems as stimuli lead immediately or may lead to a requested behaviour as well as providing an appropriate surrounding for a desirable environment friendly behaviour (Thomas, 1996). The development and evaluation of smart feedback-systems which enable occupants to understand and to react properly to the energy concept of a building are a future challenge in the field of post-occupancy evaluation as well as in the long run for updating certification systems.

The database will be enlarged by further surveys. For a more area-wide application we developed a time- and cost-effective survey instrument including a computer-based questionnaire and an easy to handle evaluation procedure for the Facility Management staff respectively personal from the real estate market (s. 4.4). A questionnaire for the Facility Management staff itself considering aspects like energy controlling and occupant behavior has recently been launched as complement to occupant surveys.

Further research will focus on certificated buildings to learn more about the relationship between the predicted outcome based on standards and the subjective ratings obtained from occupant surveys. For this purpose Correspondence Analysis is a helpful statistical method which allows exploring relationships between building characteristics and occupant satisfaction due to simultaneous computations of ordinal as well as categorical variables. An important approach to validate relevant structures in the data is multilevel analysis; the advantage over normal regression analyses is that the level of building and the level of individuals can be computed simultaneously. Another aim is to gain more reference scores from a variety of building types to prove if benchmarks for various building types (certificated, refurbished or old existing buildings) should be specified.

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