

A Systematic Method for Improving Indoor Environment Quality through Occupant Satisfaction Surveys

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SUMMARY

A systematic method for assessing and improving indoor environment quality (IEQ) is developed for existing and occupied office buildings. The method begins with an occupant satisfaction survey that is directed to everyone working in a building. The structure of the questions follows a pattern that offers valuable information of the technical reasons leading to dissatisfaction. The questions assess satisfaction with the following IEQ areas: office layout, office furnishings, thermal comfort, indoor air quality, lighting, acoustics, and building cleanliness and maintenance.

A database of 25 office buildings in Southern Finland has been collected. The average value of all indoor environment factors in these 25 buildings is 0,85 in scale from -3 to +3. This average value can be used as a benchmark value to compare workplaces to each other. Office layout, office furnishings, lighting and cleaning have received higher scores than thermal comfort, air quality and acoustics. Also the variation between buildings has been bigger in thermal comfort, air quality and acoustics. These are also the areas where most of the technical problems have been found. In each building the occupant perception map lays the foundation for auditing and evaluating the indoor environment quality and for locating the possible technical problems.

INTRODUCTION

Well-being of people and environmental issues are some of the major concerns of our European societies today. Several hundreds of thousands of people die too early due to environment in Europe each year. Increased hospital admissions, extra medication and millions of lost working days are not only a financial issue but above all they influence the quality of our everyday life. [1]

People in modern societies spend most of their time (90%) in indoor spaces such as at home, work, school and in vehicles. Improving the quality of indoor environment enhances well-being and productivity of people. Prevention of dissatisfaction created by poor indoor environment and disoperation of technical systems needs to be our aim.

There are many effects of inappropriate indoor environment quality, like increased need to keep breaks during work, decreased concentration or fatigue. In extreme cases problems can lead to absence from work due to permanent or temporary health effects like headache, eye, skin, throat or nose irritation, thermal stress, allergy or asthma. [2]

Productivity of work is one of the most important factors influencing the profitability of business. Often other factors like cost of work or material are determined by external reasons. Good indoor environment improves productivity quicker than changes in working habits or skills, especially if indoor environment has not been in focus before. In a typical company operating in office environment 90 % of total company costs consist of employees' salaries. The rest of the costs include workplace related investment and running costs. International research has proven a development of 2-10 % in workers' productivity, when indoor environment has been improved. [3]

Indoor environment can create dissatisfaction and health problems for users due to various reasons. Often the reason is the performance of technical systems. In many cases technical problems are local and that is why it is difficult to find and locate them. Occupants complain about too hot or too cold temperatures during summer, too hot or too cold temperatures during winter, draughts from ventilation system, stuffy or stale indoor air or lack of sound privacy in open plan offices. At the same time average physical measures (e.g. room air temperature) and average occupant satisfaction may show high comfort.

When occupant satisfaction for thermal environment is known, the indoor climate category can be specified based on CEN Standard prEN 15251 (draft) "Criteria for the Indoor Environment including thermal, indoor air quality, light and noise", published in 2005 [4]. This standard specifies the three categories of indoor environment that shall be selected for a space to be conditioned (see Table 1 for recommended criteria and categories for the thermal environment).

Table 1. Recommended criteria and categories for the thermal environment according to CEN prEN 15251

Category	Thermal State of the body as a whole		Local Discomfort			
	Predicted percentage of dissatisfied	Predicted Mean Vote	Percentage of dissatisfied due to draft	Percentage of dissatisfied due to temperature difference	Percentage of dissatisfied due to warm of cool floor	Percentage of dissatisfied due to radiant asymmetry
	PPD [%]	PMV [-]	DR [%]	[%]	[%]	[%]
A	< 6	-0,2 ...0,2	< 15	< 3	< 10	< 5
B	< 10	-0,5 ...0,5	< 20	< 5	< 10	< 5
C	< 15	-0,7 ...0,7	< 25	< 10	< 15	< 10

Occupant satisfaction with the average thermal conditions can be translated to performance of workers (Fig. 1). That could be used as a tool to estimate the potential productivity improvement and furthermore to calculate the total investment potential.

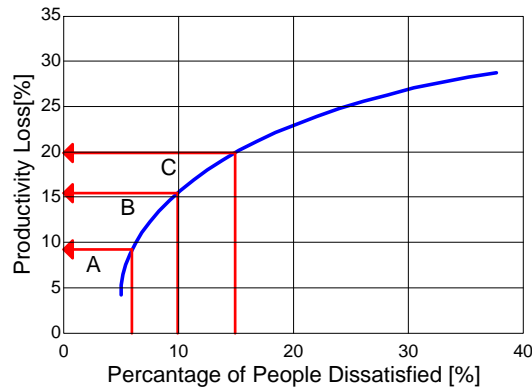


Figure 1. Linkage between percentage of dissatisfied people for thermal comfort (%) and productivity loss (%) [5].

METHODS

A systematic method for assessing and improving indoor environment quality (IEQ) is developed for existing and occupied office buildings. The method begins with an occupant satisfaction survey [6] that is directed to everyone working in a building. The structure of the questions follows a pattern that offers valuable information of the technical reasons leading to dissatisfaction. Questions focus on the human experience of indoor environment, not leading respondents directly to problems or symptoms. By using the occupant satisfaction survey all comments, also the silent comments, can be collected and taken into account when deciding on improvement actions. The questions assess satisfaction with the following IEQ areas: office layout, office furnishings, thermal comfort, indoor air quality, lighting, acoustics, and building cleanliness and maintenance.

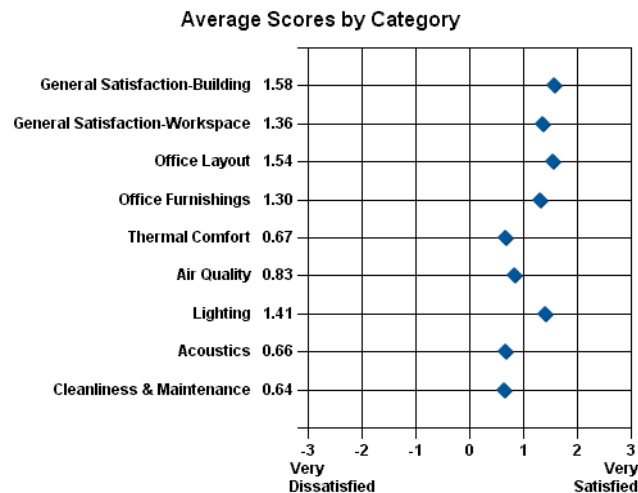


Figure 2. Average occupant satisfaction survey results normally show good values in many areas of indoor environment. [6]

Average satisfaction values between different evaluation areas (Fig. 2) do not vary as much as the local values between different areas of a building. This is why it is important to analyze results not only at building level, but also to locate the possible dissatisfaction more exactly into floors and facades. This helps to allocate actions to specific areas where they are needed. Furthermore, if the exact problems have been localized it is often possible to optimize the

HVAC-system so that both the energy usage of the system and the dissatisfaction of users can be reduced at the same time (e.g. when users complain too cold room air during summer).

Table 2 presents an example of an occupant perception map.

Table 2. Occupant perception map (% of dissatisfied people) on different floors and facades helps to identify and locate indoor environment problems.

		All	2nd floor	3rd floor	4th floor	5th floor	6th floor	North	South
General satisfaction	Building	3%	3%	0%	0%	13%	7%	3%	0%
	Workplace	5%	3%	6%	0%	29%	0%	0%	14%
Office furnishings	Comfort	10%	15%	12%	8%	0%	6%	7%	0%
	Adjustment	10%	9%	15%	9%	0%	13%	10%	14%
Thermal comfort		26%	36%	12%	58%	0%	35%	19%	43%
Air quality		20%	39%	12%	8%	25%	12%	10%	43%
Lighting	Quantity	9%	15%	6%	25%	0%	0%	0%	29%
	Quality	12%	12%	12%	17%	13%	12%	16%	0%
Acoustic quality	Sound level	16%	15%	21%	33%	13%	6%	10%	43%
	Acoustic privacy	32%	21%	36%	58%	25%	35%	16%	57%

As an example, we can calculate the productivity improvement potential of e.g. thermal environment presented in Table 2. There 26 % of the personnel are dissatisfied or very dissatisfied with the thermal environment. 25 % of the personnel also think that the present conditions interfere significantly with their ability to get their job done. If the quality level of indoor environment is improved to class A (CEN prEN 15251), the improvement in performance according to scientific studies is 5.8 %. Total monetary benefit for increasing the productivity of 100 people is €290.000 per year with annual labor cost of €50.000 per person. Total possible investment for improving thermal conditions is €1.680.900 with five years of repayment time and 3.0 % of interest rate.

A technical analysis requiring multidisciplinary knowledge is conducted in building areas where more than 30 % of respondents are dissatisfied. Systems creating and maintaining indoor environments consist of many components that are usually provided by different companies. Cross-scientific team of people representing various aspects of technical services conducts the technical analysis in the building. Improvement actions are determined based on the results of the survey and the technical analysis.

Sometimes technical problems are more complicated to solve, especially if there are any doubts of local thermal conditions e.g. drought. In those cases a full-scale mock-up can be built into laboratory conditions to find a technical solution. Another option is to use CFD simulations, but then it is critical to know the real boundary conditions of the specific terminal unit and the heat loads in the room space.

RESULTS

A database of 25 office buildings occupying 5200 people in Southern Finland has been collected. The smallest building was with 30 occupants and the largest building occupied 1200 people. The average value of all indoor environment factors of all 25 buildings is 0,85 in scale from -3 to +3. The highest average value has been 1,24 and the lowest 0,42. This average value can be used as a benchmark value to compare workplaces to each other (Fig. 3).

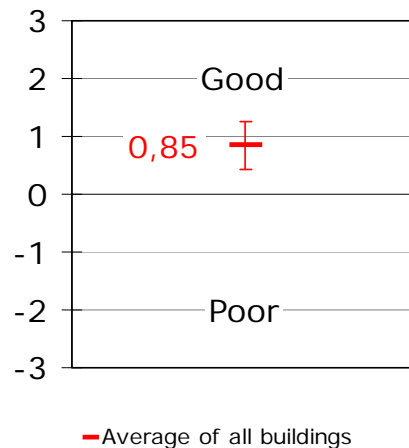


Figure 3. The average value of all indoor environment areas of all 25 studied buildings can be used as a benchmark value to compare workplaces to each other.

When searching technical improvement areas in buildings it is more valuable to present each indoor environment area separately. The evaluation of a building does not necessarily describe the magnitude of problems, because in occupants' evaluation the scale of different elements varies. Office layout, office furnishings, lighting and cleaning have received higher scores than thermal comfort, air quality and acoustics. The average values of each indoor environment area in the database of 25 buildings are in descending order:

- Lighting 1,25
- Building in general 1,23
- Office furnishings 1,22
- Office layout 1,20
- Workspace in general 1,12
- Cleaning 1,03
- Technical maintenance 0,97
- Indoor air quality 0,83
- Thermal comfort 0,49
- Acoustics 0,18

Also the variation is bigger in thermal comfort, indoor air quality and acoustics (Fig. 4). These are also the areas where most of the technical problems have been found. Occupants in office buildings complain mostly about:

- Too cold temperatures,
- Draughts from ventilation system,
- Stuffy or stale indoor air,
- Cold radiation of windows,
- Lack of sound privacy in open plan offices and
- Poor quality of cleaning service.

The typical technical reasons have been:

- Non-balanced ductworks or pipe works,
- Diffusers, which do not have a proper throw pattern
- Chilled beams, which are out of optimum operation range
- Lack of planning in room acoustics

- Operation of building management system.

All the analyzed buildings have typical Scandinavian room systems: chilled beams and mixed flow systems.

Sometimes reason has been a device failure, but too often it is just a change in office layout or change in usage of space. Changes have been completed in furniture and wall layout, but no adaptation of technical systems has been made. Also the combination of air diffusion, warm or cold window surface and layout of office furnishings may create unexpected airflows in the space.

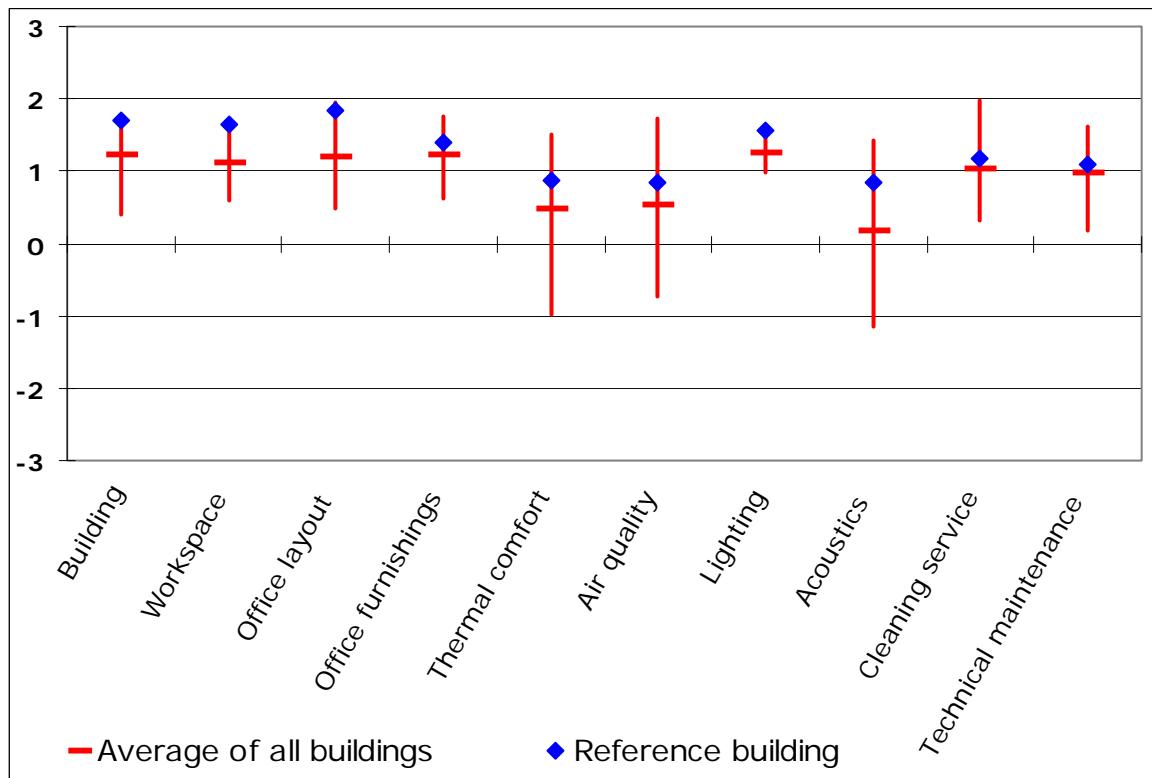


Figure 4. The average values and variations of each indoor environment area concerning 25 studied buildings.

In each building the benchmark values (Fig. 4) in association with occupant perception map (Table 2) lay the foundation for auditing and evaluating the indoor environment quality and for locating the possible technical problems.

DISCUSSION

The average value of occupant satisfaction survey (mean value of all indoor environment areas) can be used as a benchmark value when comparing workplaces to each other. It could also be the basis of indoor environment rating of buildings in the future and become a part of a holistic building labeling, where the mandatory part is energy labeling (based on Energy Performance of Buildings Directive). However, it is challenging to draw detailed conclusions of technical problems from the average occupant satisfaction only. There are several buildings, where serious problems related to indoor environment have been found in some parts of building even when the average satisfaction has shown excellent conditions.

The reason why office layout, office furnishings, lighting and cleaning get generally speaking higher scores than thermal comfort, air quality and acoustics can not be specified based on this material. Maybe people are more aware of thermal comfort, air quality and acoustics and that is why they are more critical about them. Or the other more likely option is, that the quality of thermal comfort, air quality and acoustics are poor in office environment. Technical problems found in all cases, where dissatisfaction is high, favors the latter assumption. However more research is needed in this area before any final conclusions can be drawn.

CONCLUSIONS

Occupants are an important source of information about indoor environment quality. Even though physical measures describe (numerically accurately) parts of the indoor environment only the perceived quality determines the functionality of the space to workers. People create the outcome of the work and therefore indoor environment's only purpose is to support the human performance and wellbeing. It is essential to measure the perception of people towards different indoor environment factors and in different parts of a building in order to find and correct the problems that affect human performance most. Even when the average satisfaction shows high scores there may exist major problems in some parts of the building. Occupant perception map is a beneficial tool to systematically solve the indoor environment related problems.

Many different vendors create thermal comfort, air quality and acoustics and therefore the end result is nobody's responsibility. There are no companies providing integration services to enable a satisfactory indoor environment within thermal conditions, air quality and acoustics. A more holistic approach of indoor environment development and maintenance is needed in order to provide satisfactory workplaces for people to perform at their best.

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