

# **Comparison of productivity and absenteeism effects of indoor environmental quality in offices**

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## **ABSTRACT**

This paper is an overview of literature that investigates the effects of general environmental quality, indoor air pollution, ventilation rates, thermal comfort, temperature control and number of persons per workspace on productivity and sickness absenteeism in offices. The review includes both self-reported effects and objective measurements of productivity and absenteeism and both laboratory studies and field investigations. It turns out that a good general environmental quality increases productivity by 10–15% and decreases sickness absenteeism by 2.5 percentpoint. The most influential single factor is the absence of air pollution sources, which increases productivity by 3–7% and decreases sickness absenteeism by 1.5 percentpoint. The results of different studies produce a fairly consistent picture, in the sense that: (1) the effects found through self-report and objective measurement are comparable; (2) the effects of general environmental quality and of the sum of the discrete factors are comparable; (3) the effects found in laboratory studies and field investigations are comparable; and (4) the patterns of effects of the discrete factors on productivity on the one hand and on absenteeism on the other are comparable. From this, it is concluded that the estimates of productivity and absenteeism effects are valid for practical purposes. Finally, the medical and psychological mechanisms by which indoor environment influences productivity and absenteeism are discussed. From this it follows that in the case of high autonomy/creativity jobs the estimates for productivity gains need to be corrected downwards and that in the case of lack of management concern for workers' complaints the estimates for productivity gains and absenteeism decrease need to be corrected upwards.

## **INDEX TERMS**

Productivity; Sickness absenteeism; Indoor air quality; Thermal comfort; Office building

## **INTRODUCTION**

(Fisk and Rosenfield, 1997) propose a twofold halving of empirically found productivity effects of the indoor environment. A first halving because they assume only half of people's actual work is influenced by practical variations in the indoor environment. A second halving because they assume that the variations of the indoor environmental parameters in the empirical studies are larger than those expected to be found in real situations. The authors of this paper submit that since then empirical studies have been published which do not show the assumed restrictions and that it is now possible to make valid estimates of the productivity effects of indoor air quality (IAQ) and thermal comfort without the proposed correction factors. Furthermore, new data about the effects of IAQ and thermal comfort on sickness absenteeism have been published, so the relation between productivity and absenteeism effects can be studied.

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## METHODS

From journals, conference proceedings and doctoral theses in the field of indoor air quality, those research results were selected that are relevant to the central issue. This was done on the basis of reading abstracts and full publications, because the relevant information is often hidden in the publications and not detectable by keywords search. The search restricted itself to office buildings.

Concerning productivity effects studies were selected that (1) presented the workers/subjects with a complete working routine that was representative for actual work, (2) objectively measured performance in a way that reflected the output relevant for actual work, and (3) presented the workers/subjects with variations in IAQ and thermal comfort that are representative for normal office buildings. Studies that complied with these criteria could include both laboratory studies and field studies. In addition self-report data concerning productivity were included to study the relation between these and objective measures.

Concerning absenteeism, studies were selected that measured objectively registered sickness absenteeism in situations where there were intra- or inter-building differences in IAQ or thermal comfort. In addition, self-report data concerning absenteeism were included to study the relation between self-report and objective measures or when objective measures were lacking. The results are presented beginning with a short historical overview.

## RESULTS

### Productivity and the Total Indoor Environment

The first productivity studies stem from the late 1980s. They used self-report data only and were restricted to the effects of the total indoor environment. The results were that, with a generally good IAQ, thermal comfort productivity was on average 12% higher than in office buildings with a less well indoor environment (Wilson and Hedge, 1987, Raw *et al.*, 1990). Later studies in the early 1990s that used objective measures showed a productivity gain with a generally good IAQ and thermal comfort of 10–15% (Clements-Croome, 2000).

### Productivity and the Impact of Separate Aspects

From the second half of the nineties research focused towards the effects of separate aspects of the indoor environment. Wargocki (1998) found that removing an air pollution source from a work space increased productivity 3% with administrative tasks and 7% with word processing. The pollution source that was or was not present during the experiment consisted of old soiled floor covering that was representative for what can be present in a real office building. (Wargocki *et al.*, 2000) found that increasing the ventilation rate in a range that is representative for normal office buildings increases productivity 2% with administrative tasks and 1% with word processing. In both studies by Wargocki the tasks were lifelike and the productivity measures were relevant for actual office work.

Studies into the effects of thermal comfort show a complex relationship between temperature and mental work performance. Often the effects are large (up to 30%); mostly, these are found with deviations from neutrality that are not found in normal office buildings. To overcome these problems it has been proposed that in office buildings, with their already restricted temperature range, the amount to which the workers can control the temperature in their own rooms is really the most decisive factor for comfort and thus for productivity (Wyon 2000). This is supported by the data. Both laboratory and field studies show that providing the workers with effective temperature control increases the objectively measured productivity 2–3% (Clements-Croome, 2000).

Several studies (e.g. Wilson and Hedge, 1987), show a strong influence of the number of workplaces in an office room on IAQ and thermal comfort complaints. It is, therefore, to be expected that this variable will also influence productivity. Several studies in (Clements-Croome, 2000) show that in cellular offices productivity is higher than in open plan offices, although the effect cannot be quantified.

### **Absenteeism and the Total Indoor Environment**

Research into the influence of the office indoor environment on absenteeism shows the same historical development as in the case of productivity. The first studies used self-reports only, then registered absenteeism was measured and finally the impact of separate aspects was studied. (Preller *et al.*, 1990) collected self-reports of absenteeism from 7000 workers in 60 office buildings. The results indicated that a generally well indoor environment would decrease absenteeism by 1–2 percentpoint. Jones *et al.* (1995) show that in office buildings with low IAQ and thermal complaint levels, the registered absenteeism is on average 2.5 percentpoint lower than in buildings with high complaint levels.

### **Absenteeism and the Impact of Separate Aspects**

Milton *et al.* (2000) studied the impact of separate environmental aspects on registered absenteeism with the following results:

humidifiers in the HVAC system: 1.5 percentpoint higher absenteeism;  
lower outdoor air supply: 0.5 percentpoint higher absenteeism;

Most of the humidifiers were of the cold water type, which can cause microbial growth, which can pollute the ventilation air. Lower air supply meant lower than 40 m<sup>3</sup> per person per hour.

The effect of temperature control for the workers has not been studied with registered absenteeism. Self-report data from Preller *et al.* (1990) indicate that absenteeism is 0.5 percentpoint lower when the workers have adequate temperature control.

No data have been found regarding the effect of the number of workplaces per room on absenteeism. Jaakola and Heinonen (1993) show that workers in cellular offices have a lower risk of getting influenza and common cold than workers in open plan offices. This implicates that absenteeism will be lower in cellular offices. Quantitative conclusions about registered absenteeism cannot be drawn, however.

## **DISCUSSION**

Table 1 shows an overview of the effects of the indoor environment on productivity and absenteeism.

**Table 1** Indicators of productivity and sickness absenteeism effects in offices

Environmental variable	Productivity gain	Absenteeism decrease
IEQ generally well	10–15%	2.5 percentpoint
No air pollution sources	3–7%	1.5 percentpoint
Sufficient ventilation	1–2%	0.5 percentpoint
Temperature control	2–3%	0.5 percentpoint
Cellular offices	Gain	Decrease

The validity of these indicators for practical purposes is supported by the following:

1. The fair match between self-report and objective results for the effects of the total environment on both productivity and absenteeism.

2. The fair match between total effects and the sum of effects of individual aspects. In the case of productivity the sum of the effect of the individual aspects is 6–12% plus an unknown gain compared to a total effect of 10–15%. In the case of absenteeism the sum of the effect of the individual aspects is 2.5 percentpoint plus an unknown decrease compared to a total effect of 2.5 percentpoint.
3. The fair match between laboratory and field data in the case of temperature control.
4. The fair match between the pattern of magnitude of impact of separate aspects on productivity and absenteeism. With both dependant variables the impact of air pollution sources appears to be much greater than the impact of ventilation and temperature control.

### **The Mechanisms of Productivity and Absenteeism Effects**

Wargocki (1998) shows that decreased productivity as a result of inadequate IAQ often goes hand in hand with headache and fatigue. Wyon (2000) shows that high temperatures diminish cognitive skills, which can be explained as an effect on the nervous system and the senses. Nemecek (1980) found that in the case of internal noise, like from colleagues and office machinery, the negative effects of noise turn out to be negatively correlated with localizability, predictability, experienced necessity, controllability and lack of informative content of the noise. The negative effects are thus largest when the noises occupy the organism's information processing capacity, so that less capacity is left for the actual task. The same goes for inadequate lighting and VDU quality (Ankrum, 1999). They diminish the readability of texts, which requires extra effort, so less of the organism's capacity is left for the actual task. In general, flaws in the indoor environment diminish the organism's processing capacity and/or occupy a part of this capacity. Therefore, less capacity is left for the actual task.

The impact of the indoor environment on sickness absenteeism is a topic of increasing attention. However, the discussion of causal mechanisms limits itself almost solely to the direct path of invalidating illness to absenteeism. In general, there are two paths along which work related burdens can increase sickness absenteeism (Oversloot, 1995):

1. The burdens directly cause the illness or the medical complaints, e.g. lifting too heavy loads causes back pain or contact with contaminated blood causes infectious disease.
2. The burden does not in itself cause illness but it does cause dissatisfaction with the work environment and diminished loyalty to the organization. When an employee suffers from a non-serious illness (e.g. common cold or headache) he or she is not necessarily incapable of working, but the diminished loyalty will increase the probability that he or she reports ill. Moreover, when the complaints decrease at the end of the sickness period, the employee has a certain latitude of choice to report well earlier or later, and if possible he or she will postpone reporting well (e.g. from Friday till Monday) if loyalty to the organization is low. This, of course, also depends on the legal and cultural tolerance towards reporting ill, which can vary considerably among organizations and countries. Because this mechanism normally only works in the case of non-serious illness and its relative effects are greater in the case of short sick leaves it leads to an increase of short-term absenteeism rather than of long-term absenteeism.

Published data indicate that indoor air problems increase sickness absenteeism along the two paths described earlier. On the one hand, inadequate ventilation and indoor air pollution increase the probability of infectious illnesses like influenza and the common cold (see the literature review in: Milton *et al.*, 2000). On the other hand, Robertson *et al.* (1990) report that when workers from the same organization move from a building part with good IAQ to a part with poor IAQ, the registered sickness absenteeism increases in *all* diagnostic categories and not only in those that are IAQ related. Workers who move in the other direction show a

decrease of absenteeism in all diagnostic categories. This indicates that poor air quality increases the probability of reporting ill and postpones reporting well even if the illness itself is not related to IAQ. Results from Milton *et al.* (2000) support this view. It turns out that in building parts with a high level of indoor air complaints there is more short-term absenteeism but less long-term absenteeism compared to building parts with a low level of complaints (Table 2), which is what would be expected if indoor air complaints would at least partly increase absenteeism *via* decreasing loyalty.

**Table 2** Annual sick-leave rates for office workers only; adapted from Milton *et al.* (2000)

Indoor air complaints	Long-term absenteeism (>10 days)	Short-term absenteeism ( $\leq 10$ days)
Low	2.17%	1.60%
High	1.30%	1.91%

The evidence that loyalty is an important intervening variable between the indoor environment and sickness absenteeism makes it plausible that it also will be between the indoor environment and productivity, in addition to the effects on information processing capacity described above. We will elaborate on this below.

### Correction of the Productivity Indicators for Type of Work and Management Style

The data used to compile the indicators in Table 1 are either from laboratory studies with tasks that are more or less repetitive or mainly based on procedures (administrative tasks, word processing—this could also include programming—or they are from field studies with average office work. For these types of work the indicators are valid. But Wargocki (1998) shows that work requiring high autonomy/creativity, like research or management, is less affected by adverse environmental conditions. It is, therefore, to be expected that in the case of work requiring high autonomy/creativity, the effect of improvement of the indoor environment on productivity will be lower than the indicators imply.

According to social-psychological equity theory (Whitley *et al.*, 1995) workers will judge the way they are treated by management primarily in terms of fairness. Two things are decisive:

1. The measure in which they experience the distribution of rewards as fair: distributive fairness.
2. The measure in which they experience the way decisions are made as fair: procedural fairness.

Loyalty to the organization is lowest when both distributive and procedural fairness are experienced as low. But as long as procedural fairness is experienced as high, loyalty will stay high even if distributive fairness is experienced as low. In practice, it often turns out that complaints about the indoor environment decrease workers' loyalty when management does not take complaints seriously. Equity theory explains this fairly well: Problems with the indoor environment are experienced as a lack of distributive fairness (as compared to other workers inside or outside the own organization). This need not decrease loyalty, as long as procedural fairness is experienced as adequate, that is, as long as management treats the complaints correctly and attentively. But when complaints are not taken seriously both distributive and procedural fairness will be experienced as inadequate and workers' loyalty to the organization will diminish. The increase in productivity and the decrease in absenteeism can thus be (much) higher than the given indicators when management started with not taking complaints seriously, but later shows it does take them seriously by taking adequate measures.

## CONCLUSION AND IMPLICATIONS

From recently published studies, indicators for the effects of IAQ and thermal comfort can be derived. The validity of these indicators for practical purposes is strengthened by the strong convergences that were found in the data. The causal mechanisms for both productivity and absenteeism appear to be rather complex, combining medical/biological and social effects. More research is needed into the interaction of the indoor environment with type of job (routine/repetitive versus autonomous/creative) and management style.

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