

Proceedings of healthy buildings 2000, vol 1

[Health & Medicine](#)



Proceedings of Healthy Buildings 2000, Vol 1 629 PRODUCTIVITY AND INDOOR ENVIRONMENT Derek Clements-Croome¹ and Li Baizhan² University of Reading, Department of Construction Management and Engineering, UK Jukes Associates, UK

ABSTRACT Surveys in several office buildings have shown that crowded work places, job dissatisfaction and physical environment are the main factors affecting productivity. The data was produced and analyzed using occupational stress indicator in conjunction with the analytical hierarchical process. Thermal problems, stuffiness, sick building syndrome factors and crowded work places were most frequent complaints. The results suggest that the productivity could be improved by 4 to 10% by improving the office environmental conditions.

KEYWORDS: SBS, productivity, thermal comfort, perceived air quality, stress

INTRODUCTION It is much higher cost to employ people than it is to maintain and operate a building, hence spending money on improving the work environment is the most cost effective way of improving productivity because of small percentage increase in productivity of 0. % to 2% can have dramatic effects on the profitability of the company. The current state of knowledge on this subject is described by Clements-Croome [1]. Practical applications of some of this knowledge is described by Oseland and Barlett [2]

METHODS This research focuses on the relationship between productivity and the indoor environment in the offices and takes into account the fact that productivity depends on other factors by using an Occupational Stress Indicator (OSI) which has been developed to include an environmental dimension [3, 4].

OSI is a job satisfaction scale involving question or statements, asking respondent to state what they think or feel about their job as whole or

specific aspects of it. Likeret scaling using five, seven or nine point scales is usually used. The OSI has been demonstrated by Arnold [5]. The occupational stress indicator is designed to gather information about groups as well as individuals and it attempts to measure the major sources of occupational pressure; occupational stress; coping mechanisms and individual differences which may moderate the impact of stress.

An environmental dimension has been built into this indicator covering temperature, ventilation, humidity, indoor air quality, lighting, noise, crowded work space and is referred to as EPOSI which has been used to gather information about the occupants in the buildings that have been surveyed. This method of self assessment provides valuable information on individual as well as group responses. The data from the questionnaire is analyzed using the analytical hierarchy process (AHP) originated by Saaty[6]. AHP uses nine point judgement scales for use with detailed questionnaires aided by semi-structured interviews.

The method is based on the theory of 630 Exposure, human responses and building investigations hierarchies and is a way of structuring complex multi-dimensional systems, by analyzing the interaction between elements in each stratum of the hierarchy in terms of their impact on elements in the stratum immediately above. It is possible to have several levels of hierarchies, but in this case five have been selected beginning with productivity followed by human factors; system factors; healthfactors; environmental factors. The questionnaires were answered by occupants across various work grades and tasks and were designed to elicit: background information about the organization and the workplace • how much the environment and the job

cause dissatisfaction • the feelings of the subject about their current working situation • the principle causal factors influencing health symptoms of occupants • which factors influence job satisfaction and productivity Semi-structured interviews were carried out to establish more details about attitudes and reasons behind responses. Office survey A detailed environmental survey was carried out at an office in Reading in 1996. The questionnaire was in five sections: Section A The Questionnaire asks the occupants to judge the physical factors in the environment covering temperature, stuffiness and draughts, dryness, indoor air quality, sunlight, lightning, noise and vibration, and crowded workplaces. Questions were also asked about personal health; job stress; job satisfaction; an overall opinion about the indoor environment; including questions about five categories of sick building syndrome covering sensory irritation; skin irritations; nervous problems; nasal and odor complaints. Section B

The questionnaire concerned subjects views on how they liked the office layout and decoration as well as questions about their job in relation to productivity. They are also asked to rate how much personal control they felt had over temperature and lighting. Four questions were asked to determine self assessed productivity covering the amount of work accomplished; quality of work; feeling of creativity; and degree of responsibility. Section C The questionnaire was concerning information which describes the characteristics of the organization, workplace and some personal information.

Occupants were then asked about human factors such as well-being; ability to perform; motivation; job satisfaction and technical competence. Finally

there was a group of questions concerned with indoor environment; weather; outdoor view; organizational factors; occupational factors; facilities and service; and personal factors. Proceedings of Healthy Buildings 2000, Vol 1 631 Section D The questionnaire was based on information gathered using EPOSI and five major human factors were identified which influence productivity (well-being, ability to perform, motivation, job satisfaction, technical competence).

Six system factors (indoor environment, weather and outdoor views, organizational aspects, occupational issues, facilities and services, personal aspects) were examined to see how they influenced the human factors. Section E The questionnaire covered interactions between sick building sickness symptoms and an array of personal, occupational and environmental factors. RESULTS Analysis of the data shows that the level of productivity by self assessment reduces as the workspace becomes more crowded, as job dissatisfaction increases and as overall dissatisfaction of the indoor environment increases. The results lead to the overall conclusion that on average the self assessed productivity could be improved by about 10% by improving the office environmental conditions. The Spearman rank-correlation coefficient, r_s , was used to assess measure of association between any two variables. The statistical analyzes of the results is given in detail by Li [7]. It was shown that a significant rank-correlation exists between self-assessed productivity and environment, job dissatisfaction and job stress, as shown in Table 1. Table 1. The association between self assessed productivity, environment and job factors.

Factor	Associated Factor	Spearman RankCorrelation Coefficient	Self-assessed productivity
Unsatisfactory indoor environment	Job stress	-0.49	Job dissatisfaction -0.36
Unsatisfactory indoor environment	Job stress	-0.21	Job dissatisfaction +0.31
Unsatisfactory indoor environment	Job stress	+0.43	Job dissatisfaction +0.36

There is unique relationship between the individual, the environment and the building they inhabit. Satisfaction with the environment. satisfaction with the environment arises from a number of issues apart from personal health ($r=0.34$), sick building syndrome symptoms ($r=0.5$), visual and aural problems ($r=0.36$), thermal problems ($r=0.49$), and crowded work space ($r=0.50$). The correlation coefficients were statistically significant for $p < 0.01$ [3, 152] = 3.92) (1) This indicates that subjects who suffer from physical environmental factors will suffer an increase in overall unsatisfactory environment which is positively related to thermal problems, crowded workspace and sick building syndrome symptoms. The multiple regression equation for job satisfaction was found to be: $JD = 1.2055 + 0.3157*JS + 0.2572 * En + 0.1023 * CS$ $r = 0.5367$, $F = 19.56 > F_{0.01} [3, 149] = 3.92$) (2) This shows that high job dissatisfaction results from job stress, crowded workspace and an overall unsatisfactory environment. For self assessed productivity, the regression equation was developed using a step wise regression procedure: $P = 6.8510 - 0.3625*En - 0.1542*JD - 0.1329*CS$ ($r = 0.5083$, $F = 14.86 > F_{0.01} [3, 132] = 3.94$) (3) The principal factors which affect self assessed productivity in the offices surveyed were an overall unsatisfactory environment, crowded workspace and job dissatisfaction.

A distinction was made between direct effects (i. e. those effects that do not result from any other variable in the model) and - secondary or indirect

effects which arise from the interaction between one or more variables in the model. (Cohen 1983). For example an overall unsatisfactory environment has a direct effect on self assessed productivity, but there is also an indirect effect because it also affects job satisfaction which in turn also affects self assessed productivity.

The total indirect effect is estimated by the product of the effects of an overall unsatisfactory environment on job satisfaction, and job satisfaction on self assessed productivity. The total effect of environment on self assessed productivity is then the result of combining the direct and indirect effects. Further analyzes showed that the most common complaints about unsatisfactory environments were those connected with high or low temperature variations; stale and stuffy air; dry or humid air. Proceedings of Healthy Buildings 2000, Vol 1 633 CONCLUSIONS

The principal conclusions were: • • • • • • • • Individual responses illustrate that the majority of respondents believed that the office environment had a direct influence on their well-being and self assessed productivity. When dissatisfaction with the environment and job were high there was a low level of self assessed productivity. Results showed that there were more occupants suffering from an overall unsatisfactory environment than from job stress and job dissatisfaction. People may be wholly satisfied with their job, but could also be quite unhappy about their work environment.

In general however people reporting negative attitudes towards the environment were also the people with high job stress and job dissatisfaction. Crowded workspaces, thermal problems, and sick building symptoms due to whatever cause were the principal complaints about

unsatisfactory environments. Nearly two thirds of the occupants thought that a 10% or more increase in their productivity was possible by improving the office environment. Results of the analysis also indicated that self assessed productivity could be improved by about 10%.

Further analysis using the AHP model illustrated that the ability to perform, and wellbeing, were the two most important human factors that influenced the productivity of occupants in the offices surveyed. These factors together with job satisfaction and indoor environment form a virtuous cluster which is highly important in designing creative workplaces. In this study there was a small effect of the outdoor environment on productivity but this was insignificant compared to the effect of the indoor environment.

Indoor air quality and pollution were the most important environmental factors influencing sick building syndrome. Compared with other personal factors (e.g. gender and type A behavior) and occupational factors, job stress was the next most significant factor which gave rise to sick building syndrome symptoms.. Results showed that the primary factors influencing productivity varied between organizations, and also between buildings or offices within the same building. This research has established a reliable methodology for evaluating self assessed productivity. Symbols

CS En F JD JS p P r rs SBS Th ----- Crowded working space (7 score) An overall unsatisfactory indoor environment (7 score) For statistical F-test Job dissatisfaction (7 score) Job stress (7 score) The level of statistical significance Self assessed productivity (9 score) The correlation coefficient Spearman rank-correlation coefficient Suffer from SBS symptoms (7 score) Suffer from thermal conditions (7 score) 634 Exposure, human responses

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