ENVIRONMENTAL QUALITY AND THE PRODUCTIVE WORKPLACE

Derek J.Clements-Croome,

Professor of Construction Engineering, The University of Reading, The School of Construction Management and Engineering, Reading, RG6 6AW, United Kingdom

1. Introduction

It is a 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 a small percentage increase in productivity of 0.1% to 2% can have dramatic effects on the profitability of the company. The current state of knowledge on this subject is described in CIBSE (1999) (4), Clements-Croome (2000) (7). Practical application of some of this knowledge is described by Oseland and Bartlett (1999) (22). Because productive environments are healthier and leaner in terms of energy consumption, gains in productivity offer energy reductions many times those offered by operation, construction and design respectively (Evans 1998; Lovins 2000) (14 & 19). Healthy buildings tend to increase productivity; save energy but require good facilities management (see Leaman and Duffy in Clements-Croome 2000)(7).

Surveys in several office buildings have shown that crowded work spaces, job dissatisfaction and the physical environment are the main factors affecting productivity (Carnevale 1992, Clements-Croome 1997)(3)(6). The data was produced and analysed using an occupational stress indicator in conjunction with the analytical hierarchical process. Thermal problems, stuffiness, sick building syndrome factors and crowded work spaces were the most frequent complaints. The results suggest that the productivity could be improved by 4 to 10% by improving the office environmental conditions.

2 How Can we Assess Building Quality?

Williams (2002) (27) describes the *Building Quality Assessment* programme (BQA) which originated in New Zealand and was introduced into Europe in 1985. The BQA system is based on a weighted evaluation of 137 factors of building design, each of which are given scores and weightings. These factors are ascribed among the nine categories and these are described in the following table.

Table 1. The BQA Categories (Williams 2000)

BQA Category	Description
Presentation	Appearance of the building & impression created
Space Functionality	Factors that determine operation of spaces
Access & Circulation	Matters concerned with access of people & goods

Amenities	Facilities or spaces for people
Business services	Electrical services & information technology
Working Environment	Working conditions of people in their work spaces
Health & Safety	Mandatory & other health or safety requirements
Structural Considerations	Building structure, construction & condition
Building Operations	Short & long term management of the building

Clearly there are other issues which could be added. It is also possible to send questionnaires out to users, suppliers and consultants across the whole spectrum of property and facilities from time to time to see how opinions and attitudes are changing. This method of analysis is very similar to the *Analytical Hierarchical Process* (AHP) developed by Saaty (1972) (24) for dealing with multiple factor problems and has been used by Clements-Croome (2000) (7) for evaluating the effect of the environment on productivity in the workplace discussed later.

Each of the categories in Table 1 are sub-divided into a number of sections; each section is further divided into a number of factors each of which are scored on a scale of 0-10. Williams (2002) (27) shows an example where twelve primary schools were appraised and given a BQA score and this was compared to the educational achievements based on *OFSTED* results. There was a strong correlation between air quality and better educational achievement.

3 The Business Value of Buildings

For many years there has been a capital cost culture in the construction industry. Certainly there is talk about running costs, depreciation and investment value in the market place. Many of the decisions in the design, construction and facilities management processes are led by capital cost arguments which often give rise to low cost but also low quality buildings. Recognition needs to be given to the fact that a building adds value to the organisations core business; Williams (2002) (27) believes that this is by far the most significant component of the financial aspect of building performance. The difficulty which remains is that of producing sufficient credible evidence for the client.

What needs to be recognised in the building design process is that there are three key attributes which interact. The *type of building,* the *facilities* provided for *environment* and *utilities*, and the *use* of the building are three inter-related facets. In practice these issues are often considered separately but their interaction is ignored. In other words form, function and human needs are the foundation for deriving architecture which not only contributes to the well-being of the individuals occupying the building but also makes a significant impact on the business organisation. Absenteeism already costs the United Kingdom economy £12bn every year (Judge 2003) (17) and a significant proportion of this figure is due to poor environmental conditions in buildings which gives rise to building sickness symptoms (www.hse.gov.uk). These lower the immune system and generally make the workplace an unhealthy place to be (Cooper 2001)(11).

Unhealthy environments not only affect the way people work but also can be de-motivating in the sense that the staff consider that they are working for a non-caring organisation.

Williams (2002) (27) work has shown that job satisfaction contributes up to 16% of output for administrative and professional staff. Further work has sought to see how premises affected job satisfaction. This study showed that a combination of convenience of location and quality of the working environment, contributed on average 25% to the total level of job satisfaction thus affecting active output by up to 4%. Since staff salaries typically are about 90% of turnover, the impact of the building is highly significant (NEMA 1989)(20). Premises costs for maintenance, energy, cleaning and administration are only about 5% of staff costs. (Osland and Willis, 2000)(23). Maintenance is important in that if it is neglected then energy will be wasted and environmental conditions will deteriorate and both of these factors will impact on productivity.

Evans et al (1998) (14) in a report entitled *The Long-term Costs of Owning and Using Buildings* for the Royal Academy of Engineering made the point that the cost of ownership and maintenance of the building is typically about 3 % of the overall cost of people working there. The report concludes that there is a good deal of evidence that the building itself if properly designed and managed can lead to significant improvements in productivity by as much 17 %. The authors conclude that the facilities manager plays a critical role in maintaining productivity levels and being responsible for operating a feedback and maintenance system which will keep the owner, and other members of the design team informed for future projects. Those who lease buildings may have a different perspective because leasing costs can swamp the normal costs of ownership; any higher productivity payback costs however are still significant.

Hodgett (1993) (15) estimated that the annualised UK building cost including capital investment is about £200 m^{-2} of which energy and plant costs are about £10 m^{-2}. Annual staff costs are about £15,000 m^{-2}. Increasing productivity by only 1% creates added value on the staff costs. The USA have taken this issue seriously and examples are given in Clements-Croome (2000) (7) and CIBSE (1999) (4). The results in Table 2 show that staff costs are 100 to 200 times the cost of energy and these costs can be off-set by a 0.5 to 1% rises in productivity. Table 2 shows that staff costs are 20 to 44 times the HVAC running costs which indicate that an increase in productivity is required to off-set these costs by 2% to 5%. The costs are some 30 times the HVAC installation costs and any change in these costs are justified if the changes produce an increase in productivity of some 3½ %. Productivity gains of just under 10% should off-set the full running and installation cost.

Table 2. Comparison of energy and staff costs for North American Offices (CIBSE 1999).

Costs	Rosenfeld	Abdou & Lorsch	EPA	Woods	BOMA
Staff costs ($\$/ft^2$ /year)	300	218	200	237	130
HVAC running costs ($\$/ft^2$ /year)	-	2-10	6	12	2.9
Energy costs ($\$/ft^2$ /year)	1.5	1-2	2	2	1.5
Ratio of staff to energy costs	200	1214-218	100	118	87
Productivity offset of energy (%)	0.5	0.5-0.9	1.0	0.9	1.2
Productivity offset (min/day per person)	2¼	2-3¾	4?	-	5

Wyon (1996) (28) states that even where there is an impact on overall productivity of as little as 0.5% then the payback time for generally upgrading unhealthy office buildings in the United States will be as low as 1.6 years. There are many surveys which have shown much larger increases in productivity than this. Li (1998) (18) showed an increase of 10% in a conventional office block in Reading, UK.

It is now important to persuade clients that sustainable building design, construction and operation save money in terms of energy and water consumptions that can also result in healthier buildings with a consequent rise in productivity. Tuomainen et al., (2002) (25), describe a Finnish office building for which the ratio of the benefits of increased ventilation, and hence higher productivity, compared with the costs of higher energy consumption were 11.5. Djukanovic et al., (2002) (13) shows that when there is an improvement in air quality then the annual benefit is at least ten times higher then the increase in annual energy maintenance costs, resulting in a pay back period for the heating, ventilating and air conditioning capital costs of less then four months.

Von Kempski (2002) (26) describes an office building built and operated according to a standard known as *performance based building* where the principal emphases were on thermal and olfactory comfort. Overall savings were equivalent to 3.9 percent of operating costs. Again, the occupant works more productively in a healthier environment so investors, clients and workers are all rewarded.

4 Methods of Performance Measurement

Ilgen (1991) (16) classified the methods of performance measurement into three categories: (1) *Physiological;* (2) *Objective* and (3) *Subjective.* The rational for using *physiological methods* is based on the reasoning that physiological measures of activation or arousal are associated with increased activity in the nervous system which is equated with an increase in stress on the operator. However, physiological measures of work load have received wide criticism regarding their validity, as well as the sensitivity of measures to contamination and the intrusive nature of the measures themselves. *Objective measures* (O'Donnell, Eggemeier (1986) (21) are frequently used to infer the amount of workload, both mental and physical. A further class of measures of workload comprises *subjective measures* (Cyfracki (1990)(12). Subjective measures of workload are applied to gain access to the subjects' perceptions of the level of load they are facing in task performance. Rating scales, questionnaires, and interviews are used to collect opinion about the workload. While these methods may not have the empirical or quantitative appeal of physiological or objective measures, it is often argued that subjective measures are more appropriate and realistic since individuals are likely to work in accordance with their feeling regardless of what physiological or behavioural performance measures suggest. Wyon (1996) (28) classified six types of productivity metrics covering simulated work diagnostic tests, embedded tasks, absenteeism records, self-assessment and use of existing measures.

5 Field Study on Productivity and Environment

Clements-Croome and Li (2000) (8) have carried out environmental surveys in several office buildings which have shown that crowded work spaces, job dissatisfaction and the physical environment are the main factors affecting productivity. The data was produced and analyzed using an *occupational stress indicator* in conjunction with the *analytical hierarchical process* (Saaty 1972)(24).

This research focused on the relationship between productivity and the indoor environment in offices and took into account the fact that productivity depends on other factors by using an *Occupational Stress Indicator* (OSI) Arnold (1998)(2) , Cooper (1988) (10). OSI is a job satisfaction scale involving questions or statements, asking respondents to state what they think or feel about their job as whole or specific aspects of it. 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 (Cooper 1988)(10). 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 (Clements-Croome 1995)(5) which has been used to gather information about the occupants in the buildings that have been surveyed. Semi-structured interviews were carried out to establish more details about attitudes and reasons behind the responses. The questionnaires (Li 1998)(18) were answered by occupants across various work grades and tasks and were designed to elicit.

5.1 Analysis of 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.

Multiple regression and correlation analysis was carried out using a computer program (SPSS). Statistical F tests and multiple correlation coefficients R were established according to Anderson (1990) (1). Regression equations were derived for overall satisfactory indoor environment. This indicated that subjects judged an increase in overall unsatisfactory environments as being due to thermal problems, crowded workspace and sick building syndrome symptoms. Further analysis 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. Similarly job dissatisfaction was due to job stress, crowded workspace and an overall unsatisfactory environment.

For self-assessed productivity (SAP), the following regression equation was developed.

$$SAP = 6.8510 - 0.3625 * En - 0.1542 * JD - 0.1329 * CS$$

$$(r = 0.5083, F = 14.86 > F_{a=0.01} [3, 132] = 3.9 \qquad (1)$$

The principal factors which affect self-assessed productivity in the offices surveyed were an overall unsatisfactory environment (En), crowded workspace (CS) and job dissatisfaction (JD).

A distinction was made between *direct* effects (ie. 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) (9). 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.

Conclusions

The lifetime cost ratios described by Evans (1998)(14) dramatically emphasises the need to consider the impact of the buildings we design on the performance of people in the workplace, hence the benefits that accrue from good design to improve effectiveness of business organisations. A diagnostic tool has been developed to assess productivity in the workplace. There is also a need to agree a building quality assessment programme similar to the one described in this paper. The next part of our research programme in this area will examine how we can model this information in a way that is amenable to clients in order to enhance their understanding of value and its impact on life cycle costs.

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Professor D Clements-Croome
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